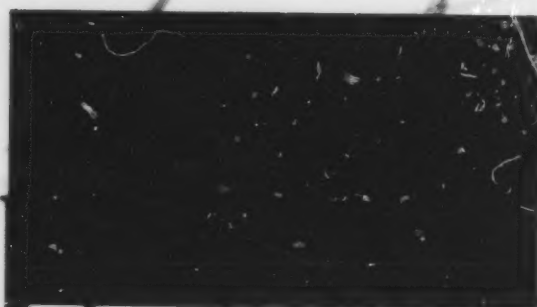


CANADA-NOVA SCOTIA
COOPERATION
AGREEMENT ON MINERAL
DEVELOPMENT

ENTENTE DE
COOPÉRATION CANADA
NOUVELLE-ÉCOSSE
SUR L'EXPLOITATION
MINÉRALE



Canada

Nova Scotia



TITLE:

A STUDY OF EFFLUENT CONTROL
AT THE CANADIAN SALT COMPANY,
PUGWASH, NOVA SCOTIA -
COST SHARED

FINAL REPORT
BY:

CANADIAN SALT COMPANY LIMITED
PUGWASH, NOVA SCOTIA

AND

JACQUES, WHITFORD AND ASSOCIATES LIMITED
DARTMOUTH, NOVA SCOTIA

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THE CANADIAN SALT COMPANY LTD.

EFFLUENT CONTROL

PUGWASH, NOVA SCOTIA

PROJECT NO. 7583

PROJECT No. 7583

REPORT TO

THE CANADIAN SALT COMPANY

ON

EFFLUENT CONTROL

PUGWASH, NOVA SCOTIA

JACQUES, WHITFORD AND ASSOCIATES LIMITED

JUNE 1992

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EXECUTIVE SUMMARY

INTRODUCTION

The Canadian Salt Company Limited (CSCL) operates an integrated underground mine and evaporator plant facility located within the village of Pugwash, Nova Scotia. Annual Rock Salt production exceeds 1.5 million tonnes to recover 1.1 million tonnes of finished rock salt and evaporator salt products.

Approximately ten years ago, the Deep Cove tailings impoundment was designed and constructed to contain solid tailings consisting primarily of undissolved salt and anhydrite. In recent years a breach of the containment area adjacent to the Pugwash river has permitted river water to flow into the tailings area at high tide and some tailings to be discharged directly to the river. The mine was directed by Nova Scotia Department of the Environment to prepare a plan to control these tailings and other discharges to the Pugwash river adjacent to the mine site.

This report presents the findings of various investigations concerning the discharge of effluents from the CSCL mine and plant site, commonly known as the brine pond, hotwell discharge, and tailings effluent. This report also addresses various options available to the mine for longer term tailings storage by expanding solid wastes tailings disposal within the Deep Cove tailings impoundment area and adjacent areas, and briefly addresses some of the concepts of underground tailings disposal. In addition, a comparative analysis of various methods to discharge the clear brine effluent into the Pugwash River Basin is presented. A numerical model of a recommended discharge arrangement was developed and analyzed.

This report was prepared by Jacques, Whitford and Associates Limited of Dartmouth, Nova Scotia. Computer assisted modelling studies were conducted by ASA Consulting of Dartmouth, Nova Scotia.

Operations

The mine is situated in northern Nova Scotia on the south shore of the Northumberland Strait, adjacent to the Pugwash river which is directly affected by the strong tidal flows of the Pugwash Basin. Site operations consist primarily of the underground mine, rock salt mill, brine production, brine treatment and evaporator plant operations and shipping. The mine recovers approximately 65% of the run of mine salt (halite) as a rock salt product, used primarily for road de-icing and a further 78,000 tonnes (85,956) of evaporator salt for sale to high purity specialty markets. Approximately 90,000 tonnes (99,180 tons) of solid mineral wastes require disposal annually, which is the subject of this report. Dissolved salt gets discharged as saline effluent at a saturation level approaching 40%.

The salt recovery operations at Pugwash are unique in that the waste rock salt is used to make the brine feed stock for the evaporator plant. The dissolver unit utilizes warmed sea water which has been previously used to cool condensers in the evaporator plant, as a dissolving media for the waste salt. The raw brine product from the dissolver also contains mineral fines, clays and anhydrite that must be purged from the brine prior to processing in the evaporator plant. The fines are discharged to an area commonly termed the Hotwell. The total combined solid discharge from both the dissolver and the Hotwell operations is estimated to be approximately 90,000 tonnes (99,180 tons) per year.

Pugwash Basin

Bathymetric studies of the Pugwash basin adjacent to the mine site suggests a maximum water depth of approximately 10 metres (32.8 ft). Measurements of water currents demonstrate consistent velocities in excess of 1 metre (3.28 ft) per second on both the flood and the ebb tide. Measurements of salinity in the basin adjacent to the mine shows values in the order of 25 ppt. There was no indication of any marked increased concentration of salinity from the measurements taken.

Observations within the existing tailings facility show the water level to be very shallow. Examination of Nellies Pond and early century photographs clearly show that Nellies Pond was part of the original shore line of Deep Cove which had been isolated by the construction of the railway earlier in the century.

Proposed Modifications

Precipitation events occasionally require that the top layer of diluted brine be displaced by saturated brine which results in overflow of the brine pond. The first step of the effluent control program is to redirect those flows to Nellies Pond. A new over flow chamber is recommended to collect the dilute brine located at the southwest corner of the brine pond and flow by gravity via a 200 mm (8 inch) pipe to Nellies Pond. This effluent would then flow to the Deep Cove tailings basin to combine with the regular tailings flow.

Recommendations are presented to collect the mineral fines from the brine clarification circuit using minor modifications to existing pipework. These fines along with a quantity of carrying water will be pumped to the tailing sump located in the dissolver area and thence into the main tailings storage location at Deep Cove.

A geotechnical investigation was carried out in the area of the breach of the existing tailings dyke, to define the nature of the foundation materials. Construction of an earth dam structure approximately 60 metres (200 ft) long is recommended to close the area of the breach. The width of the dam at the crest is 4.3 m (14 feet) which will permit vehicle traffic for the purpose of construction. The new dam would join the finger dyke and the original ground surface on the island on which the mine was constructed. We recommend that a 915 mm (36 inch) diameter culvert be installed in the dam at the time of construction, in the event that a discharge of effluent is required from that location. Recommendations on construction procedures in the near tidal zone, design slopes and slope protection, as well as the nature of the materials of construction are identified. The existing retention dyke will be used to transport the construction materials to the new dam

location site. The trafficability of the dam crest will be improved by adding a 25 cm (12 inch) thick coarse of granular material.

A detailed depositional scheme in Deep Cove is presented for approximately 90,000 tonnes (99,180 tons) of solids per year that will require storage. A 4 stage tailings deposition scheme is proposed. Stage 1 which will accommodate approximately 2 years or 180,000 tonnes (198,360 tons) of tailings, consists of conventional spigotting of tailings into the Deep Cove basin following the current procedure. Subsequent stages defined in the report will accommodate approximately 7.5 years of tailings generation. In each of these stages, additional work will be required to stack the tailings using standard excavation equipment.

The tailings pond, which will be approximately 17,650 sq. m. (190,000 sq.ft) and 1.8 m (6 ft) deep will provide for approximately 40 hrs retention time, well in excess of that required to settle the finest particle as anticipated. The proposed out flow control structure will be the existing culvert system at the east end of the Deep Cove tailings area. The normal effluent of clear brine at approximately 40% saturation will discharge at a rate of 0.14 cu.m/s (4.9 cfs).

Effluent Modelling

The oceanography of Pugwash Harbour in the area near the salt mine was considered using collected data. Currents and water levels observed over a period of 13 hours show the area is dominated by the tides. Conditions in the estuary are characterized by large tidal currents.

The analytical model considered a shoreline effluent discharge through a culvert, a single port diffuser and a multi-port diffuser. Estimates of the resulting excess brine concentration in the River from the shore outfall are within the stated objectives of 10% of ambient concentration at 300 m (990 ft) from the outfall. The other outfalls also met the stated objectives.

Numerical modelling estimates of the excess brine concentration were determined for the shore discharge which is proposed from the existing culvert structure, ranged up to about 20 ppt (parts per thousands) at high tide near the outfall. During high tide, the small embayment where the discharge culvert is located experiences the maximum excess brine concentration due to the shallow nature of the embayment. Conditions at other stages of the tide cycle are typically less than 2 ppt. In all estimates presented, the excess brine concentration drops to less than 2 ppt within 200 m (660 ft) from the contact point of the brine effluent and the River water. The existing culvert structure is adequate to disperse the effluent into the Pugwash estuary, with minimal environmental impact both under current conditions and after the proposed work is completed.



RÉSUMÉ A L'INTENTION DE L'EXÉCUTIF

INTRODUCTION

La Société Canadienne de Sel Limitée exploite une mine souterraine et une usine d'évaporation intégrées qui sont situées près du village de Pugwash en Nouvelle-Écosse. La production annuelle de sel gemme excède 1.5 tonne pour obtenir 1.1 tonne de sel évaporé et de produits de sel traité.

Il y a environ 10 ans, le bassin de retenue de Deep Cove a été conçu et construit dans le but de recueillir les résidus de traitement. Ces derniers sont surtout composés de sel et d'anhydrite non-dissous. Au cours des dernières années, une brèche s'est créée dans la zone d'endiguement adjacente à la Pugwash. Ceci a permis l'entrée, à marée haute, des eaux de la rivière dans l'aire de stockage des résidus. De ce fait, une certaine quantité de ceux-ci s'est trouvée déchargée directement dans la rivière. Le Ministère de l'environnement de la Nouvelle-Écosse a ordonné à la mine de préparer un plan pour le contrôle de ces résidus et celui des autres déversements effectués dans la partie de la rivière Pugwash qui est adjacente à la mine.

Ce rapport présente les constatations résultant de plusieurs enquêtes relatives aux effluents de la mine et de l'usine de la SCS Ltée. Ceux-ci sont communément décrits comme étant les effluents du bassin de saumure, les décharges de la source chaude et les rejets de liquides et de résidus de l'aire de Deep Cove. Ce rapport traite également de différentes options offertes à la mine pour augmenter la durée d'entreposage des résidus par l'élargissement des possibilités de décharge de ces derniers dans l'aire de Deep Cove et dans celles qui lui sont adjacentes. En outre, ce rapport fait brièvement état de quelques concepts d'évacuation et d'entreposage souterrain des résidus. On y trouve aussi

une anaiyse comparative des méthodes de déversement d'effluents de saumure claire dans le bassin de la rivière Pugwash. Un modèle numérique de gestion des déchargements recommandables a été développé et analysé.

Ce rapport a été préparé par Jacques Whitford et Associés Ltée de Dartmouth, Nouvelle-Écosse. Les études de modélisation par ordinateur ont été faites par ASA Consulting, de Dartmouth, Nouvelle-Écosse.

ACTIVITÉS D'EXPLOITATION

La mine est située dans le nord de la Nouvelle-Écosse, sur la rive sud du détroit de Northumberland, adjacente à la rivière Pugwash qui est sous l'influence des puissants courants de marée du bassin de Pugwash. Les activités d'exploitation du site sont principalement l'exploitation d'une mine souterraine et d'une installation de broyage du sel gemme, la production et le traitement de saumure, la conduite d'une installation d'évaporation et l'expédition des produits. La mine recueille approximativement 65% du sel gemme extrait à titre de produit commercialisable principalement utilisé pour le déglacage des routes et une quantité additionnelle de 78,000 tonnes de sel d'évaporation, lesquelles sont destinées au marché spécialisé su sel de haute pureté. Il reste donc approximativement 90,000 tonnes de rebuts minéraux solides qui doivent être déchargés chaque année, ce qui est l'objet de ce rapport. Le sel dissous est, pour sa part, évacué sous la forme d'un effluent salin dont la saturation est d'environ 40%.

Le procédé utilisé dans l'exploitation de Pugwash pour la récupération du sel est unique en ce sens que les rebuts de sel gemme sont utilisés pour préparer la saumure alimentant l'usine d'évaporation. La dissolution des rebuts de sel gemme est réalisée à l'aide d'eau de mer chaude provenant du circuit de refroidissement des condenseurs de l'usine d'évaporation. La saumure brute provenant de l'unité de dissoultion contient des fines minérales qui sont de l'argile et de l'anhydrite et qu'il faut éliminer de la saumure avant son traitement dans l'usine d'évaporation. Ces impuretés sont déversées dans une zone

communément appelée "la source chaude". La quantité totale de résidus solides déchargés, suite à l'opération de l'unité de dissolution et de la source chaude, est estimée à approximativement 90,000 tonnes par année.

LE BASSIN PUGWASH

Les études bathymétriques du bassin Pugwash adjacent à la mine suggèrent une profondeur d'eau maximale d'environ 10 mètres. Les relevés de vitesse des courants indiquent des vitesses constantes de plus d'un mètre par seconde lors des deux marées, haute et basse. Le mesurage de la salinité de l'eau du bassin indique des valeurs de l'ordre de 25 ppm. Ces relevés n'ont indiqué aucune concentration caractéristique de la salinité.

Les observations effectuées dans l'aire de stockage de résidus montrent que le niveau de l'eau y est très bas. L'examen du Nellies Pond et de photographies prises au début du siècle indique clairement que Nellies Pond était une partie du rivage original de Deep Cove et que peu de temps après, elle en a été isolée par la construction du chemin de fer.

MODIFICATIONS PROPOSÉES

Parfois, les phénomènes de précipitation causent le déplacement de la couche supérieure de saumure diluée par de la saumure saturée, ce qui occasionne un débordement du bassin de saumure. La première étape du programme de contrôle des effluents consiste à diriger ces déversements vers Nellies Pond. Il est recommandé de construire une nouvelle chambre de trop-plein destinée à recueillir la saumure diluée accumulée dans le coin sud-ouest du bassin de saumure et d'en assurer l'écoulement par gravité vers Nellies Pond via un conduit de 8 pouces de diamètre. Cet effluent s'écoulera ensuite vers le bassin de résidus de Deep Cove et se combinera avec l'écoulement régulier de ceux-ci.

Des recommandations sont émises quant au captage des fines minérales du circuit de clarification de la saumure. Ceci pourrait se faire grâce à des modifications mineures de la tuyauterie existante. Ces fines et l'eau dans laquelle elles sont en suspension seraient évacuées par pompage et déversées dans le puisard de résidus situé dans la zone de l'unité de dissolution à chaud et de là, acheminées vers l'aire principale de stockage de résidus de Deep Cove.

Une investigation géotechnique a été entreprise dans le but de déterminer la nature des matériaux de fondation de la digue de stockage des résidus dans la zone de rupture de la digue. Il est recommandé d'construire un barrage de terre d'environ 60 mètres de longueur pour fermer la brèche. La largeur de la crête du barrage, établie à 4.30 mètres, permettra la circulation des véhicules utilisés pendant la construction. Ce nouveau barrage réunira la digue actuelle à la surface originale du sol de l'île sur laquelle la mine se sel a été construite. Nous recommandons, lors de la construction du barrage, la pose d'un ponceau de 36 pouces de diamètre afin de parer à l'éventualité de décharge d'un effluent à partir ce cet endroit. Les recommandations concernant les procédures de construction près des la zone de marée, la détermination et la protection des pentes ainsi que la nature de matériaux a employer sont indiquées dans le rapport. La crête du barrage sera rendue plus carrossable par l'addition d'une couche de 30 cm de matériau granulaire grossier.

Un plan de dépôt détaillé est présenté pour le stockage annuel, dans Deep Cove, d'approximativement 90,000 tonnes de solides. Un plan, en quatre volets, est proposé pour le dépôt des résidus. Le premier volet permettra le dépôt des résidus de deux années, soit 180,000 tonnes et consiste à introduire ceux-ci conventionnellement dans le bassin de Deep Cove, selon la procédure actuelle. Les volets suivants, décrits dans le rapport, permettront d'accepter les résidus résultant de 7.5 années d'opération. Chacun de ces volets exigera des travaux additionnels pour l'empilement mécanique de résidus, à l'aide d'engins normaux d'excavation.

Le bassin de résidus, dont la surface sera approximativement de 13,500 mètres carrés et la profondeur environ 1.80 m permettra une période de rétention de 40 heures, ce qui bien en excès du temps de sédimentation anticipé pour les fines. La structure du contrôle d'écoulement proposé sera le système de ponceaux existants, lequel est situé dans le coin est du bassin de résidus de Deep Cove. Normalement, l'effluent de saumure saturée à 40% sera déchargé au rythme de 0.14 m³/sec.

ÉTABLISSEMENT DU MODELE D'EFFLUENCE

L'océanographie du havre de Pugwash, dans la zone voisine de la mine de sel, a été prise en considération lors de l'utilisation des données recueillies. Les courants et niveaux d'eau observés pendant une période de 13 heures ont démontré que cette zone est dominée par les effets des marées. Les conditions prévalant dans l'estuaire de la Pugwash sont caractérisés par de forts courants de marée.

Le modèle analytique a considéré la décharge riveraine d'un effluent via un ponceau, un diffuseur à orifice unique et un diffuseur à orifices multiples. L'estimation de l'excès de concentration de saumure résultant de la décharge riveraine dans la rivière se situe en deçà des objectifs prescrits, lesquels spécifient une concentration ambiante de 10% à 300 mètres de la bouche de décharge. Les autres types de décharges considérées ont également rencontré ces objectifs.

Les estimations d'excès de concentration de saumure du modèle numérique ont été effectuées pour la décharge riveraine proposée, via les ponceaux existants.

Les estimations d'excès de saumure s'étagent jusqu'à 20 parties par mille à marée haute, près de la bouche de décharge. La petite anse, dans laquelle est situé le ponceau de décharge, présente, à marée haute, le maximum d'excès de concentration de saumure en raison de la faible profondeur d'eau à cet endroit. Les concentrations relevées pendant les autres étapes du cycle de marée sont typiquement inférieures à 2 parties par mille.

Dans toutes les estimations présentées, l'excès de concentration de saumure tombe en dessous de 2 parties par mille, en dedans d'une distance de 200 mètres du point de contact de la saumure avec l'eau de la rivière.

La structure de ponceaux existante est adéquate pour la dispersion des effluents dans l'estuaire de la Pugwash et n'occasionne qu'un impact minimal sur l'environnement, tant dans les conditions actuelles qu'après l'achèvement des travaux proposés.

1.0 INTRODUCTION

The Canadian Salt Company Limited (CSCL) have operated an underground salt production mine and related surface plant facility within the village of Pugwash N.S. since the late 1950s. In recent years, the annual raw salt production has exceeded 1.5 million tonnes (1,653,467 tons), resulting in 1 million tonnes (1,102,000 tons) of finished rock salt and 71,000 tonnes (78,242 tons) of evaporator salt.

Brine for the evaporator plant is prepared by dissolving some of the waste salt to produce a saturated brine solution for use as a feed stock. Excess brine is stored in an open brine pond on site which occasionally can be diluted by rain water fall. From time to time the undersaturated brine in the pond is overflowed into the Pugwash river by new feed stock required to maintain brine quality.

A quantity of fine mineral insolubles from the salt dissolver is also carried into the Pugwash river as the treatment tank purges into the excess return flow of warm condenser water. This warm water discharge is commonly known as the hotwell discharge. The dissolver operation also generates tailings of undissolved salt and insolubles which constitute the main source of tailings which are directed to an onsite tailings pond.

Approximately 10 years ago, the tailings impoundment dyke was constructed to control the discharge of tailings into the tidal estuary adjacent to the Pugwash river. Subsequent to the construction and due to erosion of mine waste accumulations adjacent to the river, the barrier separating the tailings impoundment zone from the river was breached, permitting tide water flows into the tailings area. During the falling tide, some of the tailings are washed directly into the Pugwash river by the return flow of the tidal waters.

Examination by both the Federal and Provincial Departments of the Environment in recent years has resulted in sporadic sampling of effluent and numerous discussions with the CSCL personnel both at the mine site and at the offices of the Nova Scotia Department

of the Environment.

Following these various discussions the Nova Scotia Department of the Environment directed CSCL to prepare an Environment Control Program (ECP) relative to:

1. the tailings enclosure;
2. the hotwell discharges;
3. diffusing of liquid effluent;
4. brine discharge from the brine holding pond.

A copy of the letter is attached as appendix A.

During August 1991, the Canadian Salt Company entered into discussions with consultants to seek solutions to the effluent issue and prepare the necessary plans as required by the ECP. In October 1991, Jacques, Whitford & Associates Ltd. (JWA) were retained to provide the study for acceptable solutions.

The deliverables for the **Environmental Control Program** study as outlined by the CSCL's 'Request for Proposal' (RFP) letter of August 14, 1991 were as follows.

1. Submit an engineering plan for existing and future disposal of tailings waste, including containment of solid tailings waste to ensure deposited tailings are uninfluenced by tidal action.
2. Submit an engineering plan to deposit solid and liquid waste currently associated with the Hotwell Discharge into the new tailings disposal system referred to above.
3. Submit an engineering plan to pipeline and diffuse liquid effluent into Pugwash Basin and demonstrate minimal environmental impacts.
4. Submit an engineering plan to prevent discharge from the brine holding lagoon into Pugwash Basin.

The CSCL requires a clearly written and concise report that will address the four main areas outlined above. Additional information is required by the CSCL in the following areas:

- **Disposal of tailings waste**, existing and future; - the expected life time of the tailings pond must be identified as well as methods to extend the useful life of the present pond at the current mining rate.
 - Alternative sites for a second tailings area and its feasibility.
 - Underground storage of mine tailings with recommendations e.g. wet or dry
- **Hotwell Discharge**, solid and liquid waste diversion to tailings pond. The brine treatment system should minimize solids and improve brine quality at minimal expense (capital and operational) e.g. relocate settling tank to waste dissolver location.
- **Pipeline and diffused liquid effluent** into the Pugwash Basin and demonstrate minimum environmental impact.

Standards for Suspended Solids required to meet 50 mg/l max. and 25 mg/l average. Effluent discharge is to be controlled so that the salinity in the receiving Pugwash River basin does not exceed 10% above "ambient" salinity at a 300 meter (990 ft) distance, from the point of discharge. (CSCL's understanding of July 91 in the meeting with Regulatory Agency)

Proof of performance may be necessary prior to construction of the diffuser type outlet.

- **Brine Pond Overflow Discharge** - The overflow pipe can be redirected

into Nellies Pond or the Deep Cove Tailings area. The pipeline route and control scheme must be of standard construction and easy to monitor and clean if necessary.

In addition JWA were required to subcontract services to ASA consultants, marine environmental services, Dartmouth NS. ASA's assignment was to determine if and how the brine effluent can be released into the Pugwash River to ensure the required dilution at all times. ASA were asked to prepare a comparative analysis of the most likely options and to conduct an assessment using computer assisted numerical analysis to predict the dilutions of the effluent stream into the Pugwash River.

Personnel

The following key personnel contributed to various components of this study:

JACQUES, WHITFORD & ASSOCIATES LTD.

John A. Amirault, M.Eng., P.Eng. - Project Manager

Sue Belford, H.B.Sc. - Biologist

Demetri N. Georgiou, M.Sc., P.Eng. - Geotechnical Engineer

Brian Herteis, P.Eng., - Mining Engineer

Roger Levesque, B.Sc., P.Eng. - Geotechnical Engineer

Sandy Russell, M.Sc., P.Eng. - Civil Engineer

Brian Taylor, Ph.D., P.Eng. - Geotechnical Engineer

ASA CONSULTING LTD.

Anthony Isenor - Oceanographer

CONSULTANT

M. Waterfield P.Eng. - Special Advisor

Acknowledgement

Jacques Whitford gratefully acknowledges the assistance of all CSCL personnel who provided direction and advised on the technical aspects of the assignment. We particularly wish to thank Mr. Alan Davidson, Mr. W.M. McCormick and Mr. Dave Kirkpatrick for their willing co-operation and availability.

2.0 PROJECT DESCRIPTION

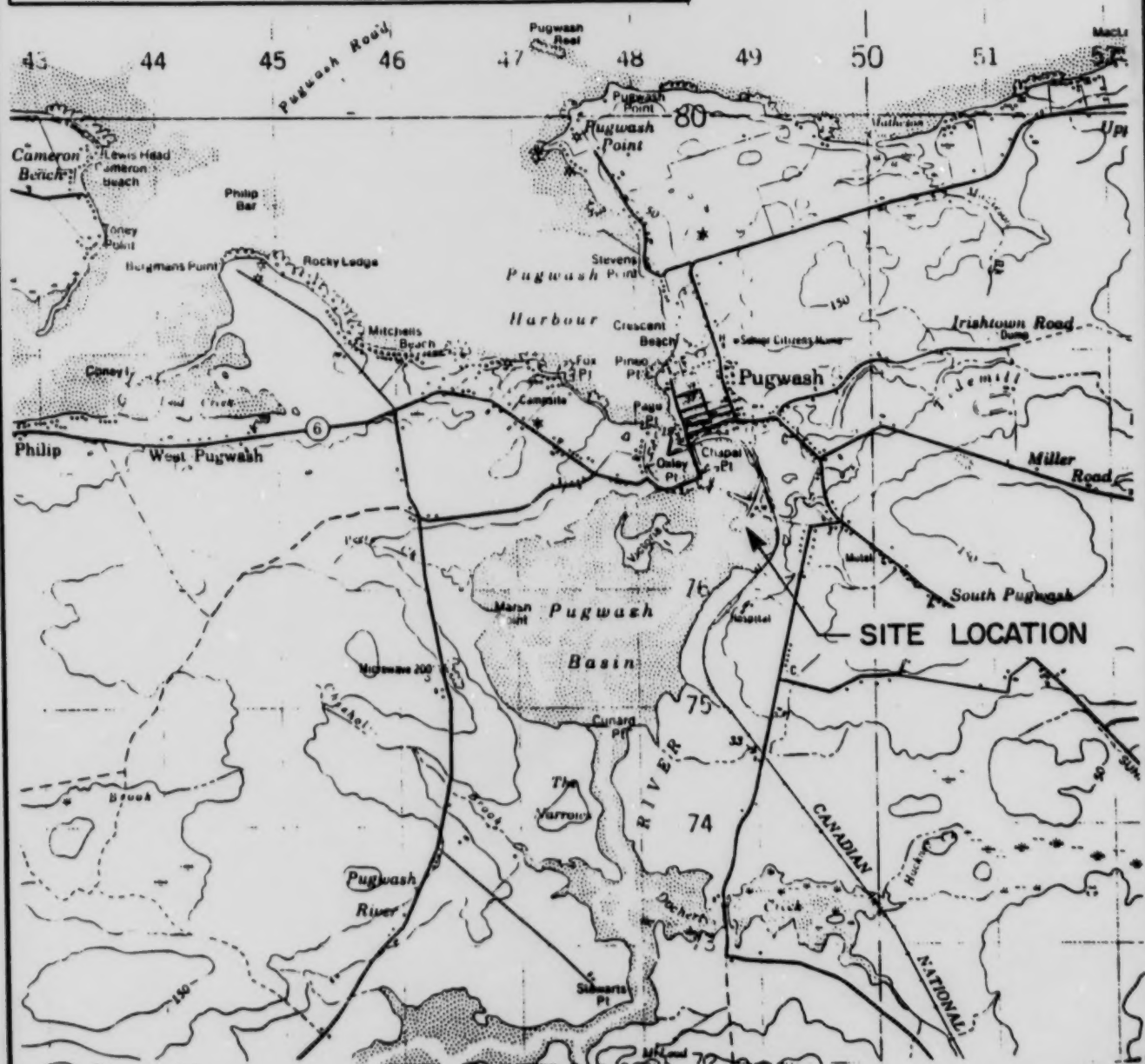
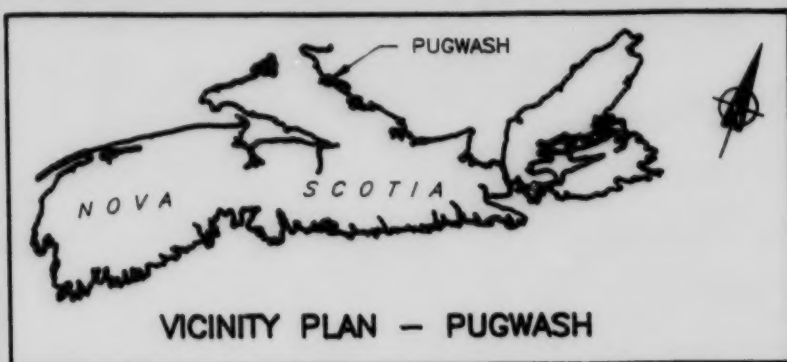
2.1 Project Location and Environmental Setting

The Canadian Salt Company Ltd. project site at Pugwash, Cumberland County, N.S., is readily accessible by paved highways 24 kilometres (15 miles) north of the Trans Canada highway 104 in Wentworth Centre N.S., or 45 kilometres (28 miles) east of Amherst N.S. Figure 2-1 illustrates the site location and access routes. The area is also accessible by railway and seasonally, by a navigatable harbour. Pugwash has a public government wharf and a tide water shipping facility which serves the CSCL.

Pugwash is situated on the Northumberland Strait at the mouth of the Pugwash harbour and the estuary of the Pugwash river basin. The area is characteristic of the gently rolling countryside of the carboniferous lowlands of Northern Nova Scotia where the topography rarely exceeds 50 metres (165 feet) in elevation and the rivers draining the area have broad estuaries opening to the Northumberland Strait.

The tidal processes of the shallow strait and the sheltered estuarial coastline are greatly influenced by the prevailing wind conditions and their directions. The winds will disrupt the natural tidal cycles and often produce extreme tidal heights and currents in the estuaries. A summary of the key features of the Pugwash estuarial environment is provided in Section 3.

The climate is described as a cool, humid, temperate climatic zone with weather displaying great variability throughout all seasons. Data published by Environment Canada for yearly normals, state the average daily temperature as 8°C (46°F) with the total precipitation at 973.7 mm (38") annually.



THE CANADIAN SALT COMPANY LIMITED
SITE LOCATION - PUGWASH SALT MINE

SCALE: 1 : 50,000



FIGURE 2.1

2.2 Site Description

The salt processing plant and associated structures are all contained within the boundaries of property owned or leased by the CSCL. Drawing 7583-2 illustrates the general site layout of the operation.

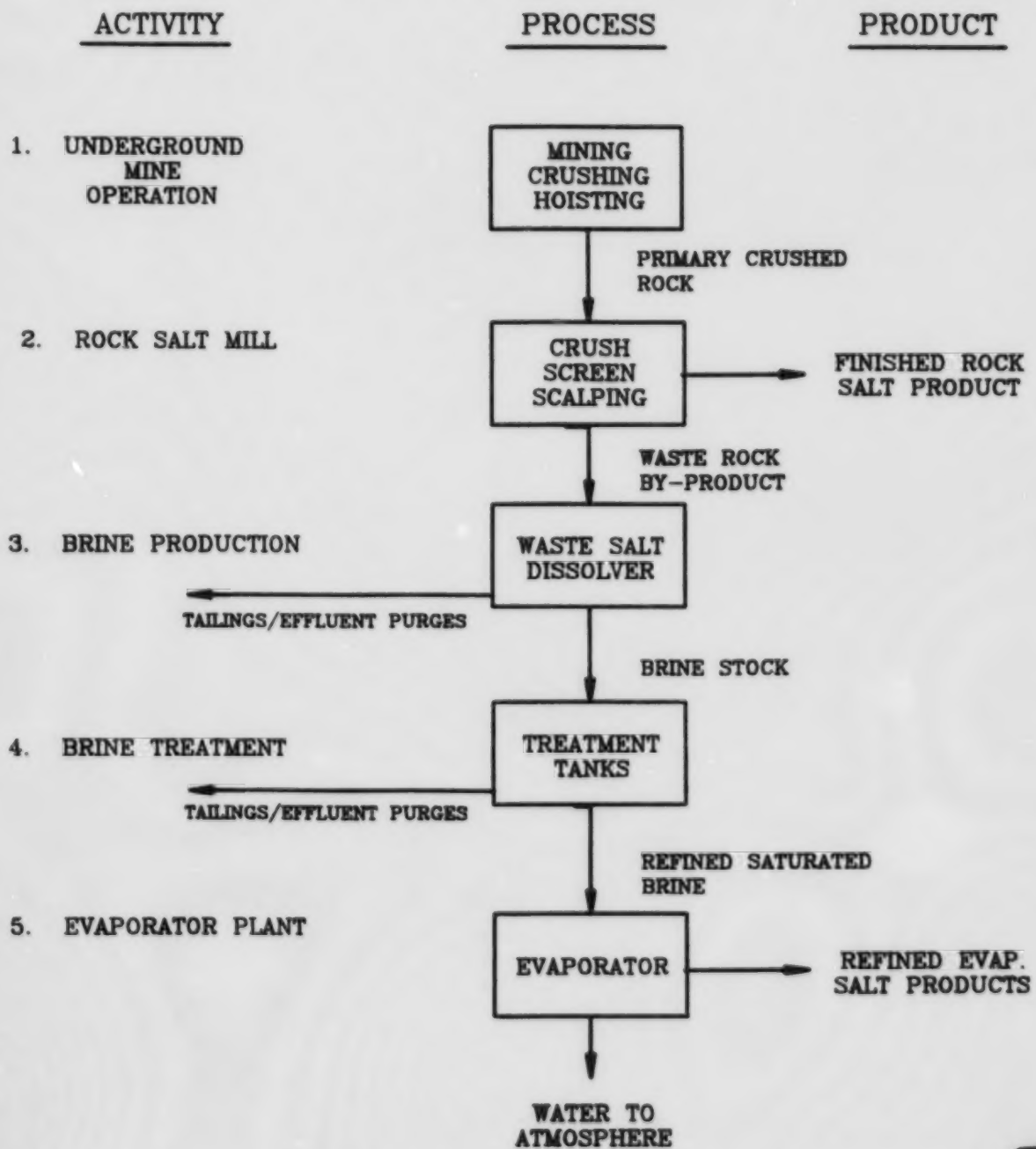
The plant site is located on a peninsula along the Pugwash River. The site is accessed by paved road from the east side of the property. A portion of the existing site area previous to the 1980s was built up by the placement of salt and gypsum-anhydrite waste rock adjacent to the mill.

The underground operation is accessed by a main and an auxiliary shaft. The rock salt plant, associated operational structures, process facilities and storage areas are centrally located. A shipping and loading dock facility is located nearby in the town of Pugwash and is accessible by road.

Evaporator salt processing involves the extraction of seawater from the Pugwash River via a pumphouse on the west side of the site. The seawater is used to cool the evaporators and the warmed water is used to dissolve the waste salt to make brine stock. The process waste effluents are currently released through the Hotwell discharge into the river and also into the Deep Cove Tailings area. The evaporator brine is stored on site and also in a storage pond at the entrance of the property.

The Deep Cove Tailings Area was created approximately 10 years ago by dyking across the cove. Nellies Pond to the east is connected to this area by way of a culvert beneath the C.N.R. route. The tailings area remained as a closed holding system with controlled discharges through two control outflow structures until it's breach in the mid 1980s. The breach area is indicated on the southwest tip of the peninsula and the proposed breach repair is shown.

THE CANADIAN SALT COMPANY LTD.
OPERATIONAL ACTIVITIES AND PROCESSES



2.3 Geology

The Pugwash mine is situated within the Windsor Group carboniferous sediments. The Windsor Group occurs as an elongated ellipsoidal outcrop pattern whose long axis trends northeast from the Pugwash area and southwest towards Roslin, approximately thirteen kilometres (eight miles) away.

Consisting primarily of limestone interbedded with red to brown shales and light grey sandstone, generally 50% of the sedimentary rocks in the Windsor group which consist of evaporites including anhydrite, gypsum, halite and potash, are precipitates from saturated seawater. The evaporite sequence in the Pugwash structure is dominated by anhydrite and halite which occur both as steeply dipping thick beds and as interbedded intervals that are transitional into thick beds. Current reserves of the halite have been established at 50 million tonnes Proven and 75 million tonnes Probable.

Impurities in the Halite are principally, gypsum, anhydrite and minor clay minerals. It is these natural minerals that constitute the tailings wastes and require on site management. The clear effluent discharge will be an unsaturated sodium chloride brine.

2.4 Salt Processing Production and Forecast

The Canadian Salt Company Limited (CSCL) underground salt mine and salt processing plant as illustrated in Figure 2.2, can be broken down into five principal process activities.

1. **Underground Mine Operation:** mining, primary crushing, hoisting
2. **Rock Salt Plant:** Crushing and screening, scalping of the crushed rock salt product by-product waste rock salt.
3. **Brine Production:** Dissolving of the waste rock salt, brine production, waste effluent, tailings discharges.

4. **Brine Treatment:** Brine clarification by-product impurity purges.
5. **Evaporator Plant:** The refined salt products.

The CSCL operational schedule is based upon three daily, 8 hour shifts, five days per week, fifty weeks per year. The process activities vary from each shift. For the purpose of this report these three daily shifts and corresponding activities have each been identified as three separate scenarios. Accordingly:

Scenario 1: 8am - 4pm Shift; Mining, Rock Salt Mill, Brine Production, Brine Treatment Evaporator Plant.

Scenario 2: 4pm - 12am Shift; Mining, Rock Salt Mill, Brine Production, Evaporator Plant

Scenario 3: 12am - 8am Shift; Evaporator Plant, Mining if required.

2.4.1 Underground Mine Operation

The mining operations have been conducted on the 630, 730, 830 and 1000 foot levels (192, 222, 253, 305 metre equivalents). The room and pillar method of extraction as been utilised with large scale blasting and excavation layouts. Rooms are driven up to 17 metres (55 feet) wide. Pillars measuring 23 metres (75 feet) square are left in place for support.

The in situ rock salt grade ranges from 85 - 96% NaCl. The remaining 4 - 15% consists of impurities which include generally gypsum-anhydrite and as well potassium salts and clay fines.

The current underground production and anticipated output in the future is 1,500,000 tonnes (1,663,467 tons) annually. The primary crushed 100mm (4") rock salt is hoisted to surface and processed during the scenario 1 and 2 shifts at a rate of approximately 450 tonnes (496 tons) per hour. Blasting operations are completed during backshift, scenario 3.

2.4.2 Rock Salt Mill Production

The milling and scalping of the hoisted material during scenarios 1 and 2 recovers 65% or 975,000 tonnes (1,074,753 tons) annually of a rock salt product for road de-icing markets. The grade of the rock salt product ranges from 93 - 95% NaCl purity depending upon intended use and market demands. The remaining 35% or 525,000 tonnes (578,713 tons) annually reports as a waste rock feed product to be used for the brine making process. Most of this waste material is of the -10 mm (-3/8") size fraction and may range from 75 - 93% NaCl purity. The impurities consist of gypsum-anhydrite, potassium salts and clay fines.

2.4.3 Brine Production Process

The water used to dissolve salt to make brine is the heated seawater returning from the evaporator plant condenser. This condenser water is nominally heated 5-10 °C (10-20 °F) above ambient and is fed to the dissolver at a rate of 150 l/s (2400 USGPM) over all scenarios. Occasionally raw, cold sea water is used directly by the dissolver when the evaporator plant is not operating.

The waste rock, a by-product of the salt processing operation during scenarios 1 and 2, is generated at a rate of 525,000 tonnes (578,713 tons) yearly or approximately 131 tonnes (144 tons)/hour. This by-product waste provides a constant feed along with the condenser water to the dissolver for brine making over the entire 16 hours of the daily operation. However, it is for only six hours on average during scenario 1 that the

dissolver brine is used to produce the high purity fully saturated brine required for the evaporation production processes. In the times that the brine treatment stream is idle or in the event that the brine feed into the treatment stream is regulated (up to 10 hours per day), the contents of the brine sump overflow into the waste sump for ultimate discharge to the tailings area as well.

The operational data provided by the CSCL indicated with the current inputs, that the dissolving efficiency of their upflow type dissolver was in the order of 80%. The CSCL quality control lab as well reported that approximately 35% of the available salt from the waste feed is lost directly to dissolver purges. These purges are discarded into the waste sump for discharge to the tailings area.

The remaining 65% of the available salt in the waste feed is overflowed from the dissolver to the brine sump to supply a brine feed to the treatment stream. This brine feed can be up to 20% oversaturated and contains other insolubles such as gypsum-anhydrite, potassium salts and clay fines.

The CSCL quality control laboratory reported that of the available salt in the by-product waste rock feed (441,000 tonnes), 35% (154,350 tonnes) is lost to the purging efforts of the dissolver. In assuming an 80% dissolver efficiency or a 20% undissolving condition, a brine containing dissolved (123,480 tonnes) and undissolved salt (30,870 tonnes) is discharged to tailings. The other 65% (286,650 tonnes) of the available salt is overflowed by the dissolver process as brine stock. This brine stock has been estimated to be 20% undissolved. For our estimates a 10% average was used, indicating a brine stock consisting of dissolved (260,591 tonnes) and undissolved salt (26,059 tonnes). For simplicity, a quantity of 84,000 tonnes of gypsum/anhydrite has been estimated for removal.

2.4.4 Brine Treatment Process

The brine treatment stream consists of three inline, gravity and flocculation treatment tanks. These include in their processing order, the settlement, roto and reactivator tanks. These tanks function to settle out and purge the impurities and undissolved salts from the feed brine and to achieve a fully saturated brine for the evaporation process.

The CSCL have reported that over the six hours of daily brine treatment, an average total 12.6 l/s (200 USGPM) of brine and wastes are purged from the three tanks. The settlement tank was reported to remove in the order of 90% of the undissolved salts and other insolubles.

The treatment process refines the brine stock to a 99.8% + NaCl purity. The three treatment tanks in combination purge 12.6 l/s (200 USGPM) of the brine stock containing the undissolved salts and the insoluble impurities. This makes up approximately 20% (21,499 tonnes) of total brine stock stream (107,494 tonnes). These purges are known as the Hotwell discharges. Since it can be assumed that the undissolved (9772 tonnes) salt is entirely removed from the feed stream, the complementing purge material is dissolved (11,727 tonnes) salt.

2.4.5 Evaporator Plant Production

The evaporator plant is operational over all three scenarios or 24 hours of each operating day. The evaporator plant at maximum can process 12.6 l/s (200 USGPM) of treated brine. This is equivalent to 14 tonnes (15.4 tons) per hour or a maximum 84,000 tonnes (92,568 tons) annually.

Upon concluding the treatment process, the refined brine containing dissolved (85,995 tonnes) salt is available for the evaporation process. The brine quality control practice

to maintain the brine pond purity through the regularly scheduled overflows of brine dissolved (7220 tonnes) salt, further reduces the available brine dissolved (78,775 tonnes) salt total.

2.4.6 Annual Production Summary and Forecast

The CSCL typical annual production stream is illustrated in Figure 2.3. which shows, the activities and processes presented earlier in this section along with the denoted rock grades and process rates. The CSCL total annual production based on the typical production stream are 975,000 tonnes of finished rock and 78,775 tonnes of possible evaporator salt production for an annual total of 1,053,775 tonnes salt product. The annual production is anticipated to remain at current levels over the next ten years. Table 2.1 presents the future yearly outputs and related process statistics.

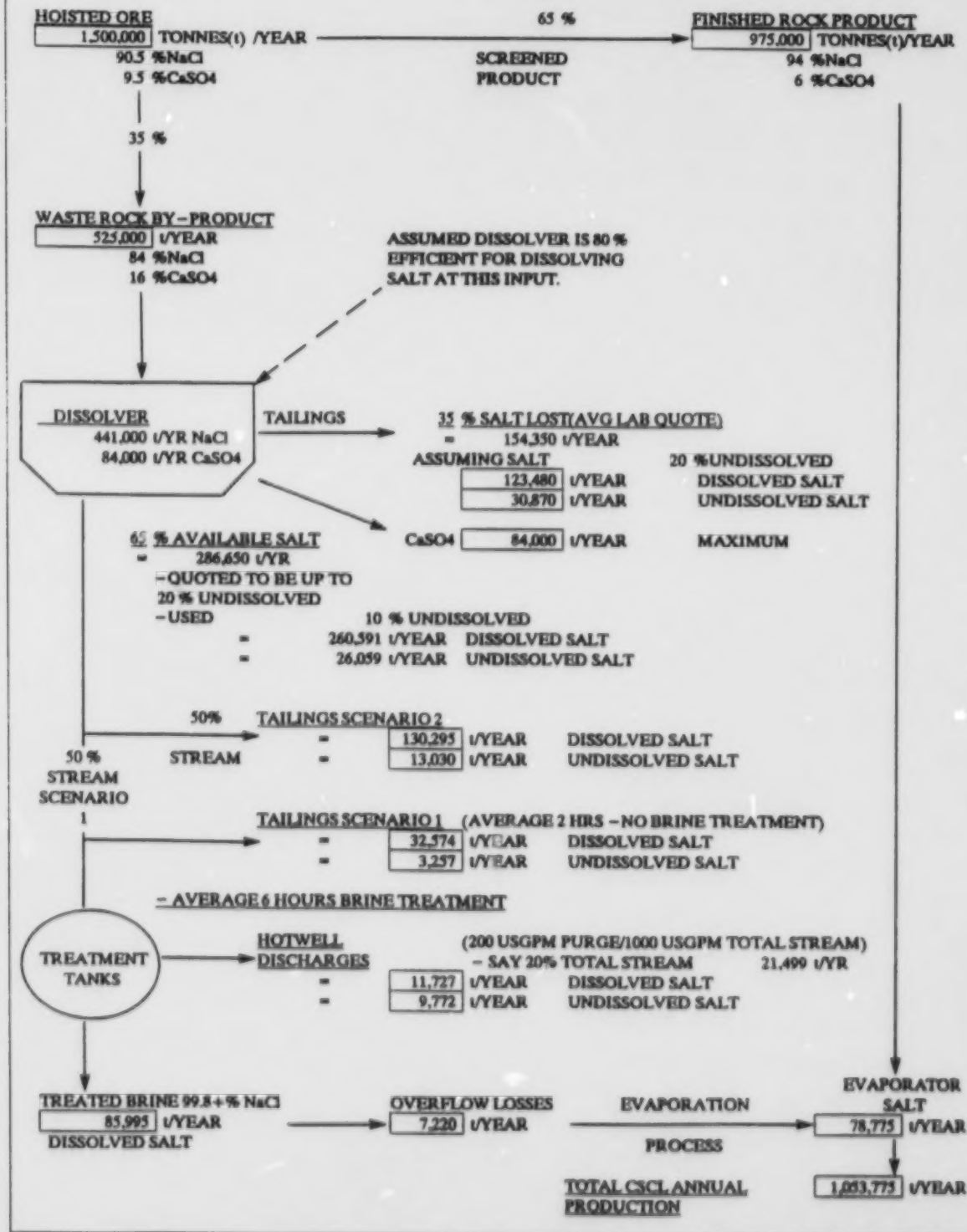
2.5 Process Flow Balances

The current brine production process was evaluated in a manner to typify an overall operational stream on an annual basis. Subsequently, before this typical operation stream could be fully defined and reconciled, the site flow balances for all three scenarios needed to be identified. In close collaboration with the CSCL and along with available information, the process flow balances for the three operational scenarios were assessed.

The process flow balances are represented and quantified in Figures 2.4 through 2.6 for all three operating scenarios. Typically for the operation, 221 l/s (3500 USGPM) of seawater is pumped from the Pugwash River to provide 32 l/s (500 USGPM) towards site utilities and 189 l/s (3000 USGPM) used as coolant for the evaporator process condensers. The returning condenser water is then collected in the Hotwell sump. From the Hotwell sump 152 l/s (2400 USGPM) of the water is pumped



THE CANADIAN SALT COMPANY LTD TYPICAL ANNUAL PRODUCTION STREAM



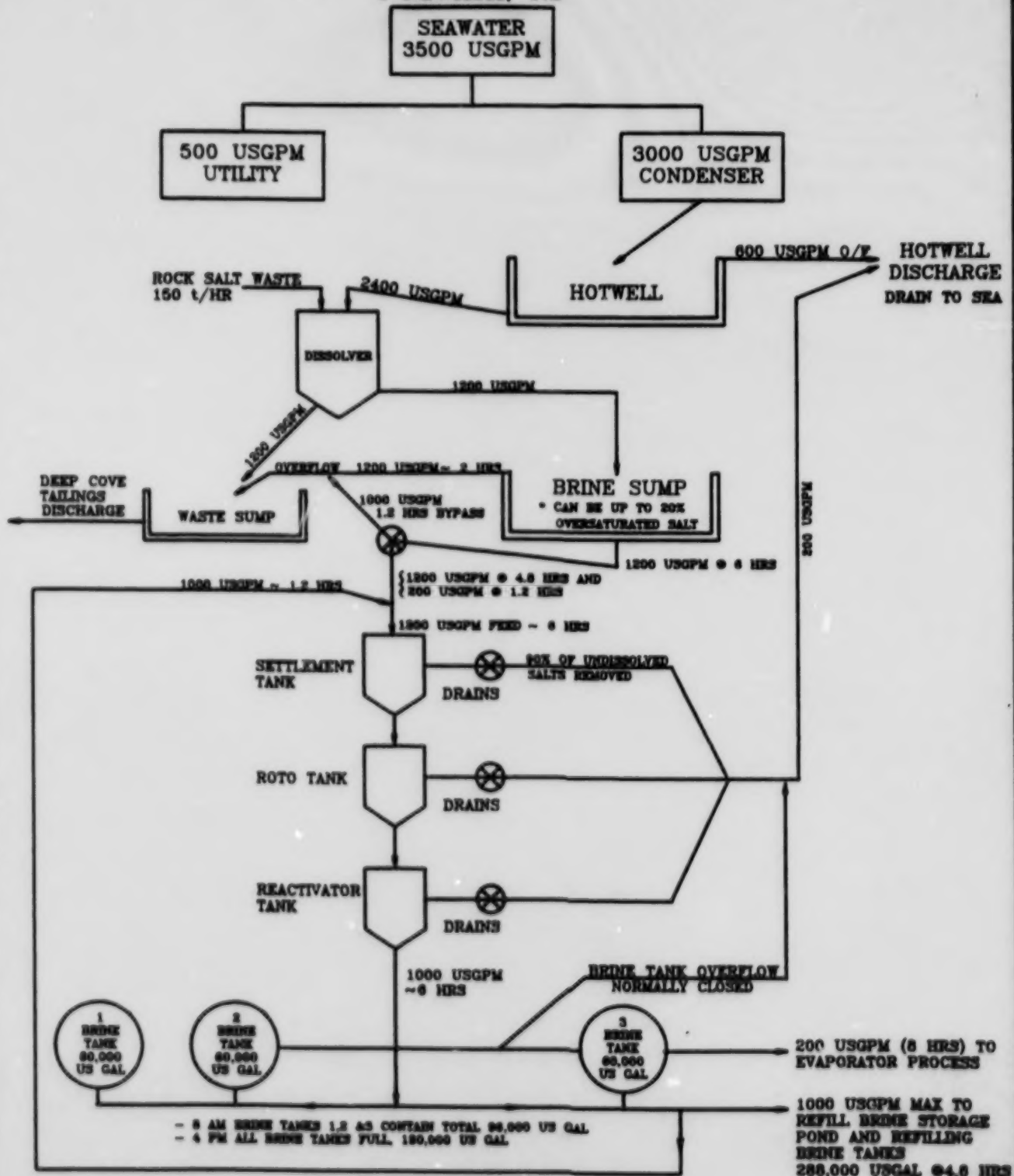
THE CANADIAN SALT COMPANY LTD.
ANNUAL PROJECTED OUTPUTS

YEAR	HOISTED ORE TONNES (TONS)	FINISHED ROCK SALT 65% TONNES (TONS)	WASTE ROCK SALT 35% TONNES (TONS)	CaSO4 DISCHARGED TO TAILINGS HOTWELL TONNES (TONS)	16% WASTE R.S. DISCHARGED TO TAILINGS HOTWELL TONNES (TONS)	UNDISSOLVED SALT DISCHARGED TO TAILINGS HOTWELL TOTAL TONNES (TONS)		DISSOLVED SALT DISCHARGED TO TAILINGS HOTWELL TOTAL TONNES (TONS)		DISSOLVED SALT TREATED BRINE TONNES (TONS)	TOTAL TONNES (TONS)		
1992 to 2001	1,500,000 (1,653,467)	975,000 (1,074,753)	525,000 (578,713)	44,911 (40,506)	* 39,069 (43,068)	47,157 (51,962)	9,772 (10,772)	56,929 (62,754)	286,349 (315,646)	11,727 (12,926)	298,076 (328,572)	85,995 (94,793)	525,000 (578,713)
TOTALS	1,500,000 (1,653,467)	975,000 (1,074,753)	525,000 (578,713)	44,911 (40,506)	39,069 (43,068)	47,157 (51,962)	9,772 (10,772)	56,929 (62,754)	286,349 (315,646)	11,727 (12,926)	298,076 (328,572)	85,995 (94,793)	525,000 (578,713)
% HOISTED ORE PRODUCTION		65.0%	35.0%	3.0%	2.6%	3.1%	0.7%	3.8%	19.1%	0.8%	TOTAL 19.9%	5.7%	35.0%
		% WASTE ROCK PRODUCT		8.55%	7.45%	8.98%	1.86%	10.84%	54.54%	2.23%	TOTAL 56.78%	16.38%	100.00%

* probable maximum solids loading



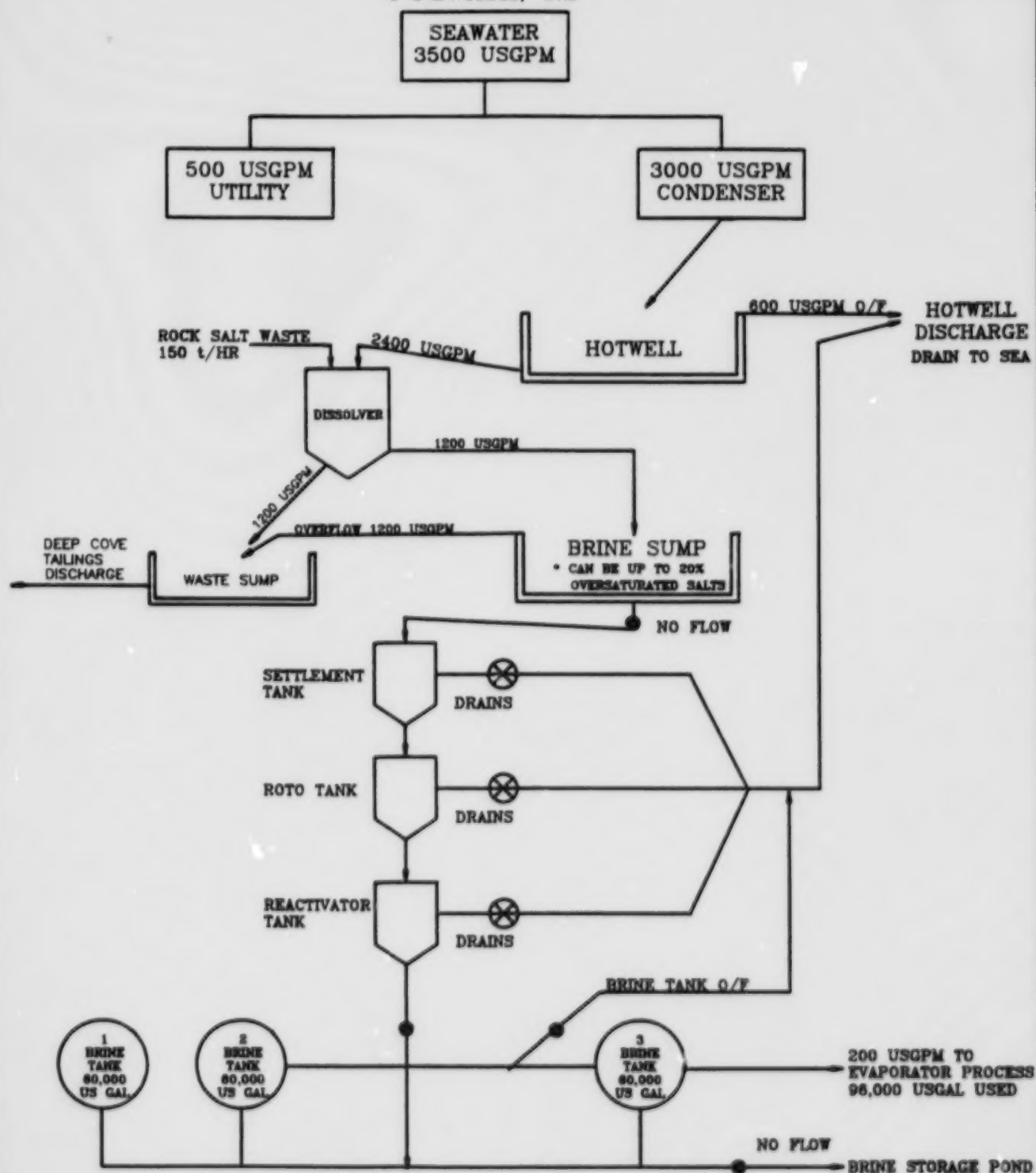
SEAWATER
3500 USGPM



PROCESS FLOW BALANCES
SCENARIO 1 8-4 SHIFT
(BRINE TREATMENT ON AVERAGE FOR 6 HOURS OF SHIFT)



THE CANADIAN SALT COMPANY LTD.
PUGWASH, NS

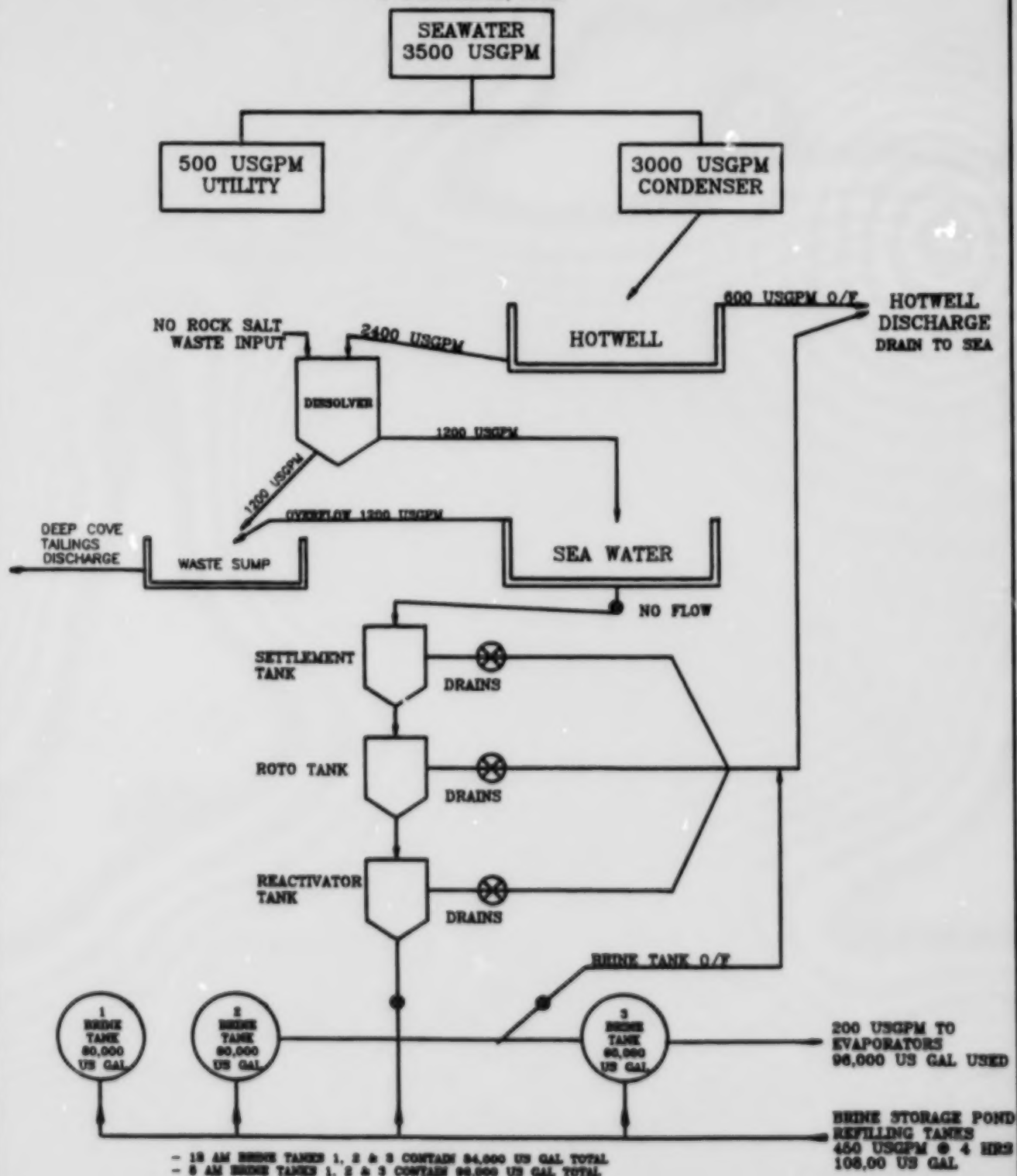


- 4 PM ALL BRINE TANKS ARE FULL, 180,000 US GAL.
- 12 AM BRINE TANKS 1, 2 & 3 CONTAIN 84,000 US GAL TOTAL

PROCESS FLOW BALANCES
SCENARIO 2 4-12 SHIFT



THE CANADIAN SALT COMPANY LTD.
PUGWASH, NS



PROCESS FLOW BALANCES
SCENARIO 3 12-8 SHIFT



**THE CANADIAN SALT COMPANY LTD
TYPICAL DAILY TREATED BRINE FLOW BALANCES**

EVENT		EVAPOR. FEED	BRINE STREAM PROD.	BRINE POND	SURPLUS BRINE	NET
SCENARIO 1 -8am to 4pm SHIFT	8am - BRINE TANK STORAGE					96,000
	EVAPORATOR FEED USAGE 200 USGPM @ 8 HRS	96,000				0
	BRINE STREAM PRODUCTION 1000 USGPM @ 6 HRS		360,000			360,000
	BRINE POND REFILLING TO FULL CAPACITY			108,000		252,000
	BRINE TANKS REFILLED TO FULL CAPACITY: 180,000 USG	180,000				252,000
	SURPLUS BRINE RE-ROUTED TO DISSOLVER BY-PASS (ALSO USED TO OVER FLOW BRINE POND WEEKLY FOR APPROX. 2HRS @ 1000 USGPM)				72,000	180,000
	4pm - BRINE TANK STORAGE TOTAL TANKS 1,2&3 FULL					180,000
SCENARIO 2 -4pm to 12am SHIFT	4pm - BRINE TANK STORAGE TOTAL TANKS 1,2&3 FULL					180,000
	EVAPORATOR FEED	96,000				84,000
	12am BRINE TANK STORAGE TOTAL					84,000
SCENARIO 3 -12am to 8am SHIFT	12am - BRINE TANK STORAGE TOTAL					84,000
	BRINE TANKS REFILLING FROM BRINE POND 450 USGPM @ 4 HRS (POND EMPTIED 108,000 USG)			108,000		192,000
	EVAPORATOR FEED	96,000				96,000
	8am BRINE STORAGE TANK TOTAL					96,000

ALL VALUES ARE IN U.S.GALLONS
1 USGPM = 0.833 Imp GPM
1 USGPM = 0.0631 litres/second

PROJECT #7583

TABLE 2.2

directly into the dissolver, leaving the remaining 38 l/s (600 USGPM) to overflow and return to the sea by way of the Hotwell discharge line.

The dissolver process for all scenarios typically divides the 152 l/s (2400 USGPM) condenser water input into two 76 l/s (1200 USGPM) streams. One stream consists of the dissolving process overflows into the brine sump and the other as the effluent purges into the waste sump for eventual discharge to the Deep Cove tailings pond. Accordingly, in Figures 2.5 and 2.6 for scenarios 2 and 3, since no brine is treated the contents of the brine sump overflow into the waste sump for discharge to the Deep Cove pond as well.

In Figure 2.4 for scenario 1 and its average 6 hours brine treatment processing, the brine sump provides a constant feed to the treatment stream. Of this 76 l/s (1200 USGPM) brine feed, 13 l/s (200 USGPM) is lost to treatment tank purges. The remaining 63 l/s (1000 USGPM) of refined brine refills the brine storage pond and brine tanks to capacity for 4.8 hours. This brine is also used to overflow the brine pond several hours weekly to maintain purity. Typically however, for the remaining 1.2 hours the brine sump feed flow is regulated and the excess brine is bypassed to the waste sump.

Table 2.2 presents the treated brine flow balances and status of the brine feed storage and supply for each shift scenario based on the typical operating schedules.

2.6 Waste/Effluent Generation

The annual waste rock salt feed input to the dissolver for brine making is 525,000 tonnes (578,713 tons). Past productions at this input, has generated 78,775 tonnes (86,800 tons) of evaporated salt. The differential net of 454,000 tonnes (500,308 tons) are discharged as waste products in the form of both dissolved and undissolved quantities of gypsum-anhydrite (CaSO_4), Salt (NaCl) and to a minor extent potassium

salts and clay sediments. The quantities of the minor constituents were not investigated further.

2.6.1 Gypsum-Anhydrite (CaSO_4) Wastes

The quantity of CaSO_4 waste produced is dependant upon its grade in the waste rock feed. This feed grade is a direct function of the grade of the hoisted rock salt material, the purity to be achieved in the finished rock product (road salt), and the milling and scalping efforts required to achieve the latter. The CSCL have reported that the CaSO_4 grade values generally range between 7 to 25%. For this report an average grade of 16% CaSO_4 has been used.

The CaSO_4 waste quantities presented in Figure 2.3 and Table 2.1 are theoretical undissolved maximums. Anhydrite (CaSO_4) is actually slowly and difficultly soluble in water. Its solubility is further increased with brine strength and temperature. Anhydrite will fully saturate with an average solubility of 0.25g CaSO_4 per 100g of saturated brine. Nonetheless, in considering the complexities associated in quantifying this over the total stream, the presentation of a wholly undissolved CaSO_4 waste component was deemed to be more conservative for our analysis and design purposes. On this basis, we assume that 525,000 tonnes (578,513 tons) of waste rock feed will produce a maximum 84,000 tonnes (92,594 tons) of CaSO_4 yearly.

By comparison, NaCl fully saturates at an average 25.0g per 100g of water under the same conditions. This represents a solubility which is approximately 100 times greater than CaSO_4 . Further considering the NaCl to CaSO_4 ratio at just over 5 to 1 in the waste feed grade and along with the solubility differences, the dissolver process should ideally have a high recovery. However such yields are not the case.

The present dissolver mechanism and associated design and/or operational inefficiencies may account for the overall dissolving and brine recovery constraints.

The CSCL personnel have noted that depending upon the source of the waste rock feed, the particle sizes of the waste feed may have the greater effect on solubility.

Anhydrite is not pure at Pugwash. What is termed anhydrite is a salt-anhydrite mixture and, in lower purity mixture the salt particles are probably surrounded by large particles of anhydrite thus limiting salt face exposure and lowering the amount of salt removed in the limited exposure to water by the dissolver.

Normally the rate of dissolution of a material is increased by reducing the size of the material particles because the available surface area is increased. However with CaSO_4 and NaCl combinations, the CSCL reports that the finer waste feed form a homogeneous mixture which tends to accumulate or slurry within the Dissolver during the dissolving process. This slurry creates complications with it's restrictions in the waste purge line capabilities and ultimately it overflows along with the brine and undissolved salt into the brine sump and onto the treatment stream.

The settlement tank which follows next in the process stream furthers the brine treatment. This gravity and flocculant controlled tank settles and removes the CaSO_4 impurities and undissolved salts. Based on two purge outlet lines and indicator discharge frequencies, the CSCL reports that 90% of the available undissolved CaSO_4 and NaCl in the stream are discharged from this tank. These discharges along with those of the roto and the reactivator treatment tanks make up the input into Hotwell discharges.

A sample from the settlement tank was obtained for chemical analysis. This sample exhibited very heavy solids loading and probably represents a near maximum suspended solids condition. The results are shown in Table 2.3. The discharge sample was composed of approximately 80% CaSO_4 and 20% NaCl . From Figure 2.3 using the predicted undissolved salt discharged to the Hotwell in the amount of 9,772 tonnes (10,772 tons), the sampled ratio was used to determine the CaSO_4 discharge

component. Under these conditions with 84,000 tonnes (92,929 tons) of CaSO_4 waste produced yearly, 39,089 tonnes (43,088 tons) of the total are estimated to discharge through the Hotwell. The remaining 44,991 tonnes (49,506 tons) would then be purged directly into the waste sump and onto the tailings area.

2.6.2 Salt (NaCl) Wastes

The NaCl wastes requiring attention are the undissolved quantities. Theoretically there is sufficient condenser water to dissolve all the available salt in the current waste rock feed. However, the dissolving process is not ideal and some salt remains undissolved.

The system characteristics and assumptions stated in earlier sections and in Figure 2.3 and Table 2.1 have noted the quantities of salt wastes generated at the various stages in the production stream. In brief, annually 56,929 tonnes (62,754 tons) of undissolved salt is possible upon the discharges from the production stream. This however does not account for the salt which dissolves in the undersaturated environment of the tailings stream.

Samples collected from various locations in the tailings, all of which were above mean high tide have shown NaCl contents less than 3%. The results of this analysis are shown in Table 2.3 and the sampling locations shown on Figure 2.7. These findings raised

questions that the undissolved salt component is not an important issue relative to storage design purposes. In discussions with CSCL we estimate that 5% of the possible total or 2,846.5 tonnes (3,136.8 tons) undissolved NaCl yearly be used for our storage design input.

2.6.3 Waste/Effluent Summary

The estimated annual waste/effluent for the CSCL operation is presented in Table 2.4. and is summarized below.

- Solid Gypsum - Anhydrite 84,000 tonnes (92,568 tons)
- Undissolved Salt 2,840 tonnes (3,130 tons)
- Dissolved Salt 53,960 tonnes (59,464 tons)

For design purposes we have utilized a waste solids loading quantity of 90,000 tonnes (99,180 tons) annually for disposal in Deep Cove.

To quantifying the dissolved salt in the waste brines, the process flow rates and durations as presented in Figures 2.4 to 2.6 were weighed against their respective saturation levels.

The dissolver purges were sampled by the CSCL in mid summer 1991 and found to be 45% saturated. The dissolver overflows (brine stock) were assumed to be 90% saturated to complement the average 10% undissolved salt content quoted earlier (section 2.4.6) for this stream and finally the treated brine is presumed 100% saturated.

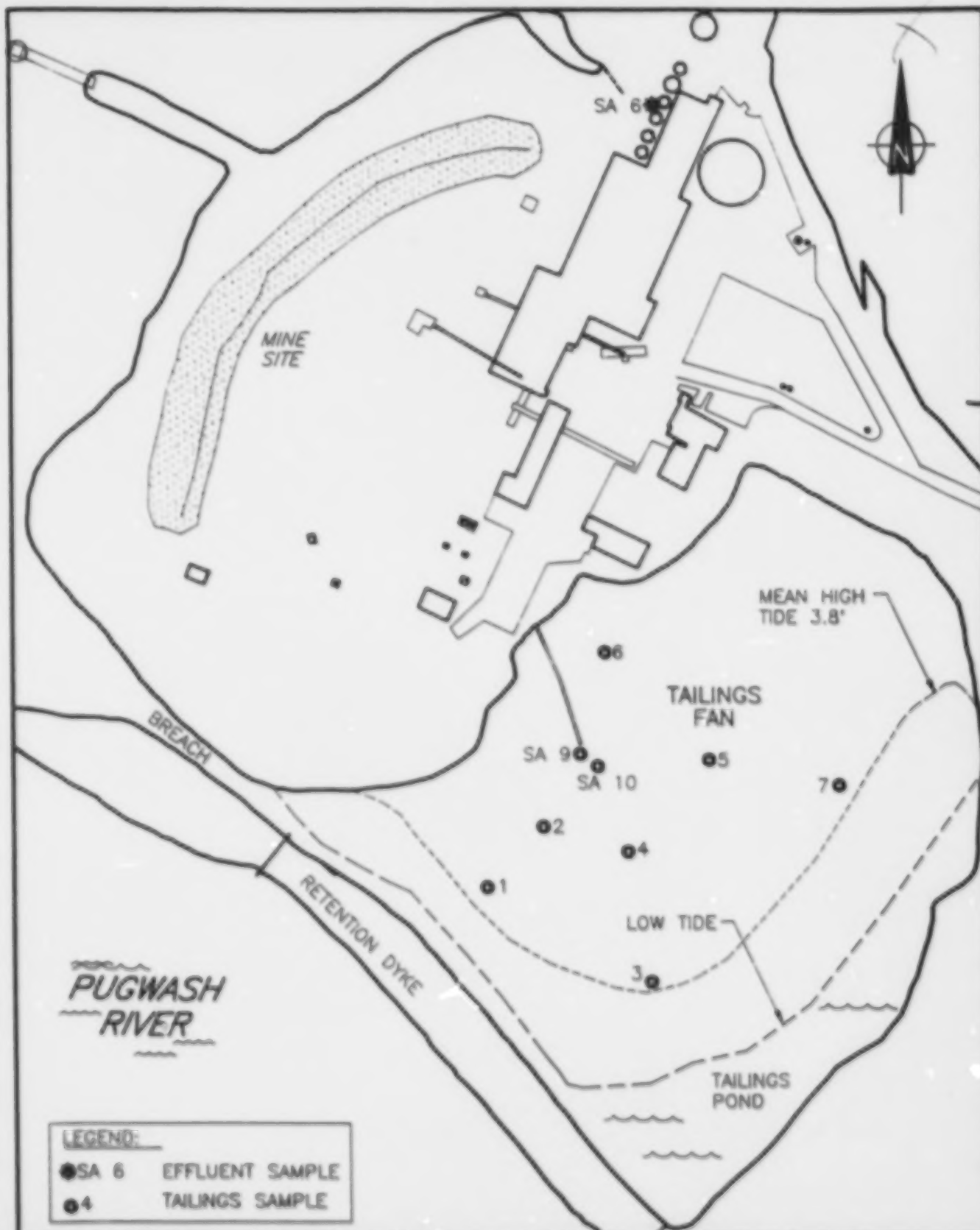
The process flow, saturation, and duration net totals for each scenario and an annual estimated average (139 l/s (2200 USGPM) @ 44% sat. over 6000 hrs) to Deep Cove tailings were calculated using an 8% saturated seawater and published brine tables. The dissolved salt is estimated to be 305,710 tonnes. This compares favourably to 298,076 tonnes dissolved salt (Table 2.1) predicted earlier in section 2.4.6 plus the additional 7,220 tonnes of dissolved salt lost to brine pond overflows, for a total 305,296 tonnes.

THE CANADIAN SALT COMPANY LTD.
EFFLUENT/TAILINGS SAMPLING ANALYSIS

Sample Location	% Composition								
	Na	Cl	CaO	SO3	NaCl	CaSO4	H2O	Gypsum	Anhydrite
<u>Treatment Stream</u>									
- Settlement Tank									
Effluent Purge (SA #6)	7.48	11.06	33.24	47.39	18.23	80.68			
<u>Deep Cove Area</u>									
- Tailings From Effluent									
Channel Downstream									
of Pipe Discharge									
- Coarse Tailings (SA #9)	0.61	0.87	39.33	47.60	1.36	80.77			
- Mixed Tailings (SA #10)	0.16	0.26	39.37	65.37	0.42	94.15			
- Insitu Tailings Samplings									
#1	0.38	0.56	39.07	53.96	0.92	91.75	1.34	6.40	86.69
#2	0.80	1.36	39.02	52.81	2.24	89.80	0.27	1.29	88.78
#3	0.33	0.53	38.11	53.58	0.87	91.10	3.37	5.10	78.36
#4	0.67	1.20	38.70	52.85	1.98	89.89	1.43	6.83	84.46
#5	0.34	0.56	38.70	53.82	0.91	91.51	1.68	8.03	85.16
#6	0.02	0.03	36.80	60.25	0.04	85.44	6.80	32.49	59.73
#7	0.02	0.03	37.77	52.10	0.04	88.59	5.93	28.33	66.17

PROJECT #7583

TABLE 2.3



THE CANADIAN SALT COMPANY LIMITED
EFFLUENT CONTROL
 PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIA
EFFLUENT/TAILINGS SAMPLE LOCATIONS

Scale: 1" = 200'

Date: 02/01/02
 Drawn by: D.A.B.

Figure No.: 2.7

App'd:



Jacques,
 Whitford and
 Associates Ltd.

THE CANADIAN SALT COMPANY LTD ANNUAL WASTE/EFFLUENT SUMMARY ESTIMATES

VARIABLES	SCENARIO 1 8am to 4pm SHIFTS	SCENARIO 2 4pm to 12am SHIFTS	SCENARIO 3 12am to 8am SHIFTS	ANNUAL ESTIMATED AVERAGES	INPUT t/year	OUTPUT t/year
WASTE SALT FEED	131 t/hr = 242,000 t @ 2000 hrs (8hrs*5days*50t/hr)	131 t/hr = 242,000 t @ 2000 hrs (8hrs*5days*50t/hr)	0	524,000 t	524,000	
DISCHARGES - SOLIDS (combined dissolver and hotwell discharges)						
CaSO ₄	21 t/hr = 42,000 t @ 2000 hrs	21 t/hr = 42,000 t @ 2000 hrs	0	14 t/hr = 84,000 t @ 6000 hrs		84,000
NaCl - predicted undissolved portage from the process discharges	14.2 t/hr = 28,400 t @ 2000 hrs	14.2 t/hr = 28,400 t @ 2000 hrs	0	9.5 t/hr = 54,800 t @ 6000 hrs - assuming 95% further dissolves upon entry into Deep Cone area or 0.5 t/hr = 2,840 t undissolved salt and 9.0 t/hr = 53,960 t dissolved salt		2,840 53,960
- WASTE BRINES FLOWS & SATURATION						
a DISSOLVER	1200 @ 45 % 2000 hrs	1200 @ 45 % 2000 hrs	2400 @ 8 % 2000 hrs	USGPM SAT. % HOURS		
b HOTWELL	200 @ 90 % 1500 hrs					
c OVERFLOW	1200 @ 90 % 500 hrs					
d BYPASS	1000 @ 90 % 200 hrs					
e BRINE POWD	1000 @ 100 % 100 hrs					
NET TOTAL	1800 @ 46.2 % 2000 hrs	2400 @ 67.5 % 2000 hrs	2400 @ 8 % 2000 hrs	2200 @ 43.89 % 6000 hrs		
SALT CONTENT*	1,518 LB/IMP GAL ** = 124,448 t	1,722 LB/IMP GAL ** = 148,230 t	0 LB/IMP GAL ** = 0 t	1,917 LB/IMP GAL ** = 105,710 t	524,000	305,710 446,510 t
TOTALS					524,000	77,490 t/YEAR

* 4% SEA WATER SALT SATURATION REMOVED FOR
THE CALCULATION OF PROCESS DISSOLVED SALT (AVERAGE FOR ESTUARINE)

NET-AVAILABLE DISSOLVED SALT
FOR EVAPORATION PRODUCTION

** OBTAINED FROM BRINE TABLES

- a DEEP CONE TAILORING DISCHARGE VIA DISSOLVER PURGE
- b CURRENT BRINE PURGE VIA TREATMENT TANKS INTO HOTWELL
- c BRINE HUMP OVERFLOW TO WASTE HUMP AFTER BRINE TREATMENT
- d REGULATED BRINE HUMP FEED STOCK BYPASS TO WASTE HUMP
- e BRINE POND QUALITY CONTROL WEEKLY OVERFLOW - 2 HRS @ 100 USGPM

CONVERSION: 1 tonne = 1.102 tons
1 USGPM = 0.833 imp GPM
1 USGPM = 0.0631 litres/second

PROJECT #7583

TABLE 2.4



2.7 Existing Disposal Methods

The existing operation at an annual production rate of 1,500,000 tonnes (1,653,467 tons) generate 446,000 tonnes (491,500 tons) of waste products for discharge from three stages of the production stream.

1. The Dissolver purges directed to the Deep Cove tailings.
2. The three treatment tank purges directed to the Hotwell discharge stream.
3. The Brine Pond overflow salt losses.

The details of the first two stages were quantified in Figures 2.3 through 2.6 and Tables 2.1 and 2.2.

2.7.1 Deep Cove Tailings

The Dissolver purges which have been discharged to the Deep Cove tailings over the past 10 years were planned to settle within a dyke impounded, 8.5 ha (21 acre) confined area. The intent of the system was to permit a controlled and regulated effluent discharge into the tidal estuary through two outfall structures. Subsequently, over the past five years due to the erosion of the mine waste accumulations adjacent to the river and impoundment dyke, the tailings area has been subject to tidal intrusions. The retreat of the tidal flows are washing some tailings directly into the Pugwash river by way of this breach with the return flow of the tidal waters.

To account for the three production process scenarios over a typical operating day, the average waste flow discharged to the Deep Cove area was determined. Through a 250 mm (10") diameter pipeline over this period it is estimated that 139 l/s (2200

USGPM) of brine @ 44% salt saturation along with purged undissolved CaSO_4 and NaCl components and other insolubles are discharged. The waste tailings are deposited by fanning out from the pipeline discharge point to the lower elevations. The undersaturated flows and precipitation events (however limited) over the fan accumulation provides further dissolving potential of the solubles.

2.7.2 Hotwell Discharges

There are three treatment tanks in the process stream; the settlement, roto and reactivator tanks. During the average 6 hour brine processing of scenario 1, the combined purges from all these tanks totalling approximately 13 l/s (200 USGPM) are discharged. These purges consisting of saturated brine, undissolved salts and insolubles are combined with the continuous Hotwell sump overflow stream.

The 38 l/s (600 USGPM) Hotwell sump overflow contains as its name may suggest, the excess return flow of the condenser heated sea water. This flow is continuous over all three shift scenarios. Only over the 6 hour brine processing for a total of 50 l/s (800 USGPM) are the waste purges included into the Hotwell discharges. All flows are conveyed through a 400 mm (16") diameter pipeline to the shoreline for discharge in the estuary.

2.7.3 Brine Overflow

The excess treated brine is piped for holding at a 14 million litre (3.5 million U.S. gallon) storage pond located near the entrance of the operation. The storage pond is uncovered therefore the brine contents are subjected to dilution with the precipitation events. To maintain the quality of the brine, the pond is occasionally overflowed to the Pugwash River, and replaced with saturated brine.

3.0 PUGWASH ESTUARY

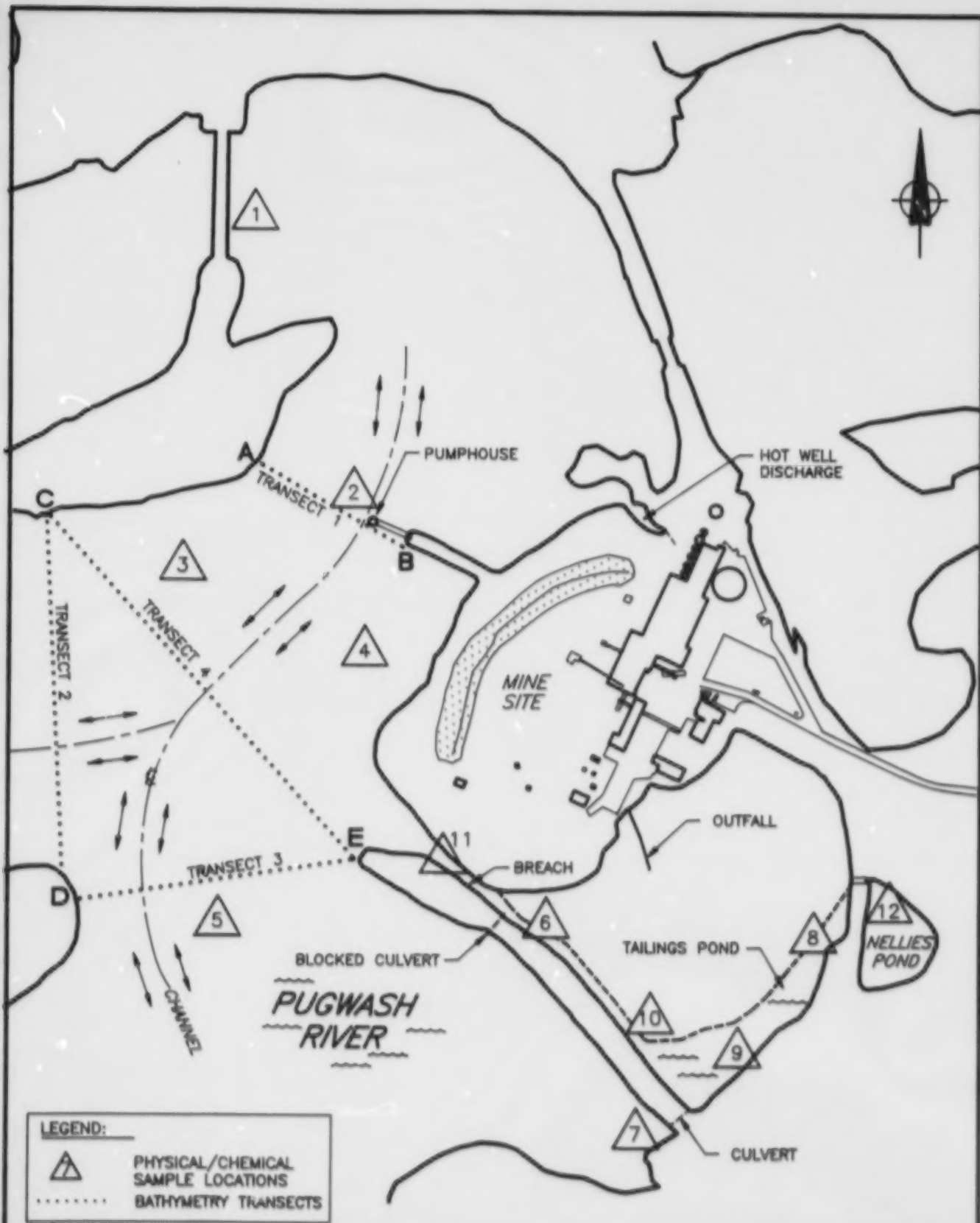
The objective of this study was to obtain an understanding of the dynamics of the tidal system of the Pugwash estuary and to characterize the physical and chemical regimes of the effluent discharge from the mine site. This was accomplished by examination of the water flow and water chemistry in the estuary adjacent to the plant and within the tailings pond.

The main issues relate to salinity of, and suspended particulate matter in, the effluent from the tailings pond compared to natural background levels in the river system. The environmental field program was structured to address the following:

- characterize the estuarial environment of Pugwash River
- investigate the tailing pond effluent
- examine the tidal influence upon Nellies Pond

3.1 Biological Environment

This section provides a description of the local environment based upon observations during the initial site reconnaissance and field surveys. Occurrences of soft-shell clams (*Mya arenaria*) and gastropods (snails) were revealed in the intertidal area of the plant frontage and Victoria Island. Seaweeds and eelgrass were also present. According to local fishermen, lobsters are fished in the estuary near the mine site. Two smelt traps were staked in intertidal areas; one near the government wharf, the other in the embayment adjacent to the mine. Harbour seals (*Phoca vitulina*) were seen in the river above the bridge during the field work.



LEGEND:



PHYSICAL/CHEMICAL
SAMPLE LOCATIONS



BATHYMETRY TRANSECTS

THE CANADIAN SALT COMPANY LIMITED
EFFLUENT CONTROL
PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIA
**LOCATION OF ENVIRONMENTAL
SURVEY STATIONS**

Scale :
1" = 400'

Drawing No.:
FIGURE 3.1

Date:
92/01/02

Drawn By:
D.A.B.

App'd:
[Signature]



**Jacques,
Whitford and
Associates Ltd.**

3.2 Bathymetry

Hydrographic measurements are a necessary component of the study for diffuser modelling and engineering designs of an effluent control structure. Navigational charts are not available for the river above the bridge. Bathymetry profiles across the channel were recorded using an echo sounder along four transects adjacent to the mine site (Figure 3.1). Elevations were derived from the tide board attached to the government wharf.

The bottom profiles are illustrated in Figure 3.2. Depth soundings were reduced to the lowest normal tide. The river basin in this area is relatively uniform, being characterized by marginal tidal flats dropping down steep side slopes to an apparently smooth bottom. Scouring is evident around the foot of the pumphouse. Observations during the field work indicated that the bottom consists, in part, of gravel and cobble. Turbulent tidal currents would likely scour away fine sediments from the bottom.

3.3 Water Quality and Flow Characteristics Methodology

Six survey stations were established within the estuary channel and near the plant periphery and one station was located in the tailings pond for a total of seven survey stations (Figure 3.1). Water quality and current measurements were recorded over one tidal cycle at each of the seven locations at approximately four hour intervals. A total of three repetitive sampling sessions were carried out at each station. On November 6, during the time interval between 0700 and 1145 the tide was rising (flood tide); between 1230 and 1700 the tide was falling (ebb tide). The duration of slack tide was approximately 30 minutes.

A second field trip on November 21, 1991 was conducted to investigate the tailings pond and Nellies Pond. Four survey stations were established within the tailings pond. One survey station was located in Nellies Pond. Replicate data were not collected for these stations.

Vertical profile data were collected through the water column at each station over three depths; surface, mid-depth and bottom. Current measurements were recorded with a TSK (Tsurumi-Seiki Co.) flowmeter. A Hydrolab H20 Surveyor 3 was employed to determine *in-situ* water quality analysis. The Hydrolab is an on-line transmitter of temperature, pH, dissolved oxygen, percent saturation, specific conductance, salinity and depth. Suspended solids levels were determined using an attenuation meter (Sea Tech Inc. Transmissometer), an optical instrument that measures light transmission through a pathway. Eleven water samples were randomly collected, using a Niskin bottle, at various depths in order to calibrate the readings.

3.3.1 Pugwash Estuary

Results from the survey clearly show the area adjacent to the mine site as the lower estuary, where the marine influence from the Northumberland Strait is dominant over freshwater derived from land drainage of the Pugwash River (Tables 3.1 to 3.7). The salinity and velocity profiles presented in Figure 3.3 depict a well-mixed estuarial system where the salinity structure is vertically homogenous. There is no defined interface between fresh and saltwater layers, typical of salt wedge and partially mixed estuaries, as a result of turbulence (Morris 1985). It was also observed that the salinity values insignificantly fluctuate between flood and ebb tides (Table 3.8).

The direction of water movement appears symmetrical along the longitudinal axis of the channel and the net flows at all depths are also relatively homogenous (Figure 3.3, Tables 3.9 to 3.11). This estuarial system is dominated by strong tidal energy and the dimensions of the estuary. The channel is relatively narrow, therefore, the mixing

process and characteristic circulation patterns are strongly influenced by lateral boundaries. Deviations from this such as the strong back eddies around the intake pumphouse and apparent salinity inversions (eg. Station 1; bottom; 0710) can cause localized distortions to the regular circulation pattern and salinity distributions created by irregular lateral boundaries (eg. the pumphouse). These localized inhomogeneities may result from turbulent mixing processes.

Analysis for suspended solids presented in Table 3.12 reveal that the high levels found in the tailings pond (Station 6) are not found outside the breach suggesting that the effluent from the breach has no measurable effect on the water of the estuary.

3.3.2 Deep Cove Tailings Pond

Water quality in the tailings pond was measured on two occasions; November 6 and November 21, 1991. During the first field trip, it was observed that on the flood tide, the tailings pond was segregated into two sections by tailings material. The smaller section is located near the breach and the larger pond is adjacent to the eastern culvert in the retention dam (Figure 3.1).

The inflow of estuarial water flows along the edge of the pond via a narrow (approximately 100mm (4 inches)), shallow (approximately 1 metre (3 foot)) channel. It was evident from observations of the waste pipe flow over the tailings, that the majority of the discharge flows in the direction of the breach. Station 6 was established near the breach to record parameters from the mine effluent in conjunction with the tidal cycle.

On November 21, 1991, the tailings pond was sampled to determine if a salinity gradient existed in relation to distance from the waste pipe and tidal influences. The water was too shallow (less than six inches) for vertical profiling. The results from

Stations 8 to 11 indicate that there is no defined salinity gradients within the tailings pond (Tables 3.13 to 3.16).

All results show that salinity inside the tailings pond is significantly higher than estuarial values. Data from Stations 4 and 7, the closest monitoring locations to the tailings, demonstrate that the effluent from both the breach and culvert are quickly assimilated into the estuary since a distinct hypersaline plume from the tailings pond was not detected.

3.3.3 Nellies Pond

Nellies Pond is subject to the daily ebb and flood of the tailings pond by direct connection through the culvert under the railbed. This pond was part of the original Deep Cove embayment. Water quality results in Table 3.17 show similar values to the tailings pond. At flood tide, the depth of Nellies Pond averaged between 1.5 to 1.8 metres (4.9 to 6 feet). At ebb tide, the depth was approximately 1 metre (3 feet). The substrate of the pond is composed of thick organic detritus of prevailing anaerobic condition. Much of the organic material is derived from the thickly vegetated sides of the depression in which the pond lies.

3.4 Environmental Guidelines

Based upon interpretation of the collected data, it appears that the existing effluents from the tailings pond and Hotwell discharge have a negligible impact upon the water quality of Pugwash River. The variation in salinity in the receiving waters does not exceed 10% above ambient. The data for suspended solids in the estuary at this sampling do not exceed the government standards of 50 mg/L maximum and 25 mg/L average in the estuary.

Table 3-1: Physical and chemical parameters at Station 1

Station 1	Surface	Mid-Depth	Bottom
Time 0710	T = 8.22	8.22	8.19
Flood Tide	C = 39.1	39.1	37.1
	DO = 8.03	7.91	7.70
Z = 0.4	pH = 7.38	Z = 8	Z = 16
(0.12)	%S = 81.6	(2.4)	(4.8)
	S = 24.8	24.7	23.7
Time 1142	T = 8.45	8.67	8.79
Flood Tide	C = 40.6	41.7	42.4
	DO = 7.10	7.37	7.26
Z = 1.5	pH = 7.54	Z = 14	Z = 26.7
(0.45)	%S = 76.3	(4.20)	(8.01)
	S = 26.1	26.7	27.3
Time 1450	T = 8.61	8.60	8.60
Ebb Tide	C = 40.1	40.0	40.0
	DO = 8.12	7.96	7.65
Z = 0.7	pH = 7.56	Z = 15.9	Z = 31.5
(0.21)	%S = 82.0	(4.77)	(9.45)
	S = 25.6	25.5	25.5

(N.B. bracketted values are in metres)

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth (ft)

Table 3-2: Physical and chemical parameters at Station 2

Station 2	Surface	Mid-Depth	Bottom
Time 0755	T= 8.21	8.24	8.25
Flood Tide	C= 40.1	40.1	40.1
Z=0.5	DO= 7.83	Z=15	Z=30
(0.15)	pH= 7.52	(4.50)	(9.0)
	%S= 81.1	78.4	76.5
	S= 25.7	25.6	25.7
Time 1200	T= 8.28	8.56	8.62
Slack Tide	C= 39.0	41.2	41.4
	DO= 7.67	7.49	7.35
Z=1.0	pH=7.53	Z=13.6	Z=26.5
(0.30)	%S= 76.3	(4.06)	(7.95)
	S= 24.3	26.5	26.6
Time 1525	T= 8.44	8.48	8.51
Ebb Tide	C= 39.1	39.3	39.3
	DO= 8.0	7.92	7.81
Z=0.4	pH= 7.55	Z=10	Z=20
(0.12)	%S= 80.8	(3.0)	(6.0)
	S= 24.9	25.1	25.1

(N.B. bracketted values are in metres)

T - temperature (°C)

C - conductivity (mS/cm)

DO - dissolved oxygen (mg/L)

%S - percent oxygen saturation

S - salinity (ppt)

Z - depth (ft)

Table 3-3: Physical and chemical parameters at Station 3

Station 3	Surface	Mid-Depth	Bottom
Time 0850	T = 8.27	8.30	8.32
Flood Tide	C = 40.3	40.3	40.3
	DO = 7.91	7.85	7.53
Z = 1.0	pH = 7.55	Z = 12.3	Z = 25.9
(0.30)7	%S = 84.3	(3.69)	(7.77)
	S = 25.7	25.8	25.8
Time 1230	T = 8.42	8.61	8.64
Slack Tide	C = 38.8	40.9	41.0
	DO = 8.11	7.77	7.47
Z = 0.6	pH = 7.54	Z = 13.7	Z = 26.6
(0.18)	%S = 81.3	(4.11)	(7.98)
	S = 24.6	26.2	26.4
Time 1600	T = 8.38	8.48	8.49
Ebb Tide	C = 38.7	38.8	38.8
	DO = 8.08	7.97	7.71
Z = 0.6	pH = 7.56	Z = 10.7	Z = 19.9
(0.18)	%S = 81.5	(3.21)	(5.97)
	S = 24.7	24.7	24.9

(N.B. bracketted values are in metres)

T - temperature (°C)

C - conductivity (mS/cm)

DO - dissolved oxygen (mg/L)

%S - percent oxygen saturation

S - salinity (ppt)

Z - depth (ft)

Table 3-4: Physical and chemical parameters at Station 4

Station 4	Surface	Mid-Depth	Bottom		
Time 0933	T = 8.30	T = 8.30	8.37		
Flood Tide	C = 40.3	C = 40.5	40.4		
	DO = 7.83	DO = 7.49	7.51		
Z = 1.0	pH = 7.55	Z = 14	pH = 7.54	Z = 28	7.55
(0.30)	%S = 78.5	(4.20)	%S = 77.0	(8.40)	73.4
	S = 25.5		S = 25.8		25.9
Time 1300	T = 8.59	T = 8.54	8.63		
Ebb Tide	C = 40.0	C = 40.1	41.1		
	DO = 7.80	DO = 7.77	7.51		
Z = 1.0	pH = 7.52	Z = 15.6	pH = 7.54	Z = 29.4	7.55
(0.30)	%S = 78.8	(4.68)	%S = 78.5	(8.82)	76.3
	S = 25.2		S = 25.6		26.2
Time 1630	T = 8.41	T = 8.48	8.5		
Ebb Tide	C = 38.4	C = 38.8	39.2		
	DO = 7.88	DO = 7.82	7.67		
Z = 1.0	pH = 7.57	Z = 12.3	pH = 7.57	Z = 23.8	7.58
(0.30)	%S = 79.1	(3.69)	%S = 78.4	(7.14)	77.3
	S = 24.4		S = 24.8		25.0

(N.B. bracketted values are in metres)

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth (ft)

Table 3-5: Physical and chemical parameters at Station 5

Station 5	Surface	Mid-Depth	Bottom
Time 1020	T = 8.43	8.44	8.47
Flood Tide	C = 40.9	41.0	40.9
	DO = 7.69	7.44	7.42
Z = 1.8	pH = 7.58	Z = 7.0	Z = 13.1
(0.54)	%S = 77.4	(2.10)	(3.93)
	S = 26.3	26.3	26.3
Time 1330	T = 8.67	8.67	8.67
Ebb Tide	C = 39.6	39.9	40.3
	DO = 7.96	7.91	7.90
Z = 0.6	pH = 7.52	Z = 9.0	Z = 18.0
(0.18)	%S = 80.5	(2.70)	(5.40)
	S = 25.4	25.4	25.6
Time 1700	T = 8.44	8.47	8.48
Ebb Tide	C = 37.5	37.8	38.9
	DO = 7.87	7.72	7.09
Z = 1.2	pH = 7.57	Z = 9.4	Z = 20.1
(0.36)	%S = 78.6	(2.82)	(6.03)
	S = 23.8	24.1	24.8

(N.B. bracketted values are in metres)

T - temperature (°C)

C - conductivity (mS/cm)

DO - dissolved oxygen (mg/L)

%S - percent oxygen saturation

S - salinity (ppt)

Z - depth (ft)

Table 3-6: Physical and chemical parameters at Station 6

Station 6	1st reading (inside)	2nd reading (in breach)	Bottom (outside berm)
Time 1050 Flood Tide Z=0.3	T = 18.5 C = 263.1 DO = 4.96 pH = 7.1 %S = 65.0 S = 168.4	10.4 48.8 6.99 7.41 76.0 32	
Time 1345 Ebb Tide Z = surface	T = 14.30 C = 85.5 DO = 2.14 pH = 6.82 %S = 60.6 S = 54.7	9.55 55.3 7.41 7.49 83.1 37.3	
Time 1723 Ebb Tide Z=0.2	T = 8.25 C = 37.6 DO = 7.91 pH = 7.59 %S = 76.7 S = 24.4		

(N.B. bracketted values are in metres)

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth (ft)



Table 3-7: Physical and chemical parameters at Station 7

Station 7	Surface	Mid-Depth	Bottom
Time 1115	T = 7.66	8.18	
Flood Tide	C = 38.1	39.2	
	DO = 7.09	6.9	
Z = 0.5	pH = 7.44	Z = 3.5 7.52	
	%S = 71.8	68.9	
	S = 24.1	25.1	
Time 1400	T = 8.58	8.64	
Ebb Tide	C = 39.9	40.4	
	DO = 7.64	7.63	
Z = 0.9	pH = 7.52	Z = 1.4 7.58	
	%S = 77.3	76.7	
	S = 25.5	25.8	
Time 1728	No water to access site		

(N.B. bracketted values are in metres)

T - temperature (°C)

C - conductivity (mS/cm)

DO - dissolved oxygen (mg/L)

%S - percent oxygen saturation

S - salinity (ppt)

Z - depth (ft)

Reynolds & Reynolds



Table 3.8: Summary of Salinity Measurements (ppt) for the Pugwash Estuary, November 6, 1991

Station #		Time	Surface	Mid-Depth	Bottom	Mean	(s.d.)
1	Flood	0710	24.8	24.7	23.7	24.4	(0.61)
	Flood	1142	26.1	26.7	26.7	26.7	(0.60)
	Ebb	1450	25.5	25.5	25.5	25.5	(0.06)
2	Flood	0755	25.7	25.6	25.7	25.7	(0.61)
	Slack	1200	24.3	26.5	26.6	25.8	(1.30)
	Ebb	1525	29.4	25.1	25.1	26.5	(2.48)
3	Flood	0850	25.7	25.8	25.8	25.8	(0.05)
	Slack	1230	24.6	26.2	26.4	25.7	(0.99)
	Ebb	1630	24.7	24.7	24.9	24.8	(0.12)
4	Flood	0933	25.5	25.8	25.9	25.7	(0.21)
	Ebb	1300	25.2	25.6	26.2	25.7	(0.50)
	Ebb	1630	24.4	24.8	25.0	24.7	(0.31)
5	Flood	1020	26.3	26.3	23.6	26.3	(0.00)
	Ebb	1330	25.4	25.4	25.6	25.5	(0.12)
	Ebb	1700	23.8	24.1	24.8	24.2	(0.51)
6	Flood	1050	168.4				
	Ebb	1345	54.7				
	Ebb	1723	24.4				
7	Flood	1115	24.1		25.1	24.6	(0.71)
	Ebb	1400	25.5		25.8	25.7	(0.21)
	Ebb	1728	No water to access site				

Table 3.9: Water Current Measurements in the Pugwash Estuary, November 6, 1991

Station #	Time	Depth		Current Velocity			
		Feet	Metres	m/s	mean	Knots	mean
1	0710	3	0.9	1.46		2.85	
		8	2.4	0.89	1.07	1.74	2.08
		16	4.8	0.85		1.66	
2	0755	3.0	1.0	1.75		3.40	
		15	4.5	1.39	1.32	2.72	2.58
		30	9.0	0.83		1.62	
3	0850	1.0	0.30	1.11		2.15	
		12.3	3.69	1.27	1.07	2.47	2.58
		25.9	7.77	0.84		1.64	
4	Back eddy - no data						
5	1020	2.0	0.54	0.46		0.90	
		7.0	2.10	0.45	0.46	0.88	0.90
		13.1	3.93	0.47		0.91	
6	Inside tailings pond no depth for current meter						
7	Backwater - no flow						

Table 3.10: Water Current Measurements in the Pugwash Estuary, November 6, 1991

Station #	Time	Depth		Current Velocity			
		Feet	Metres	m/s	mean	Knots	mean
1	Slack Tide						
2	1200	1.0	0.3	0.87		1.66	
		13.6	4.1	0.91	0.81	1.76	1.57
		26.5	7.95	0.65		1.28	
3	1230	1.0	0.18	0.81		1.56	
		13.7	4.11	0.91	0.85	1.76	1.64
		26.6	7.98	0.82		1.59	
4	1300	1.0	0.30	0.66		1.29	
		15.6	4.68	0.98	0.85	1.89	1.66
		29.4	8.82	0.92		1.80	
5	1330	1.0	0.18	0.88		1.71	
		9.0	2.70	0.96	0.93	1.87	1.81
		18.0	5.40	0.95		1.86	
6	Inside tailings pond no depth for current meter						
7	Backwater - no flow						

Table 3.11: Water Current Measurements in the Pugwash Estuary, November 6, 1991

Station #	Time	Depth		Current Velocity			
		Feet	Metres	m/s	mean	Knots	mean
1	1450	3.0	0.9	1.00		1.95	
		15.9	4.7	1.02	1.00	2.00	1.96
		31.5	9.45	0.98		1.92	
2	1525	1.0	0.12	1.34		2.61	
		10.0	3.00	1.31	1.20	2.54	2.33
		20.0	6.00	0.94		1.84	
3	1600	0.6	0.18	1.02		1.99	
		10.7	3.21	0.91	0.92	1.78	1.79
		19.9	5.97	0.82		1.59	
4	1620	1.0	0.30	0.87		1.69	
		12.3	3.69	0.77	0.77	1.50	1.50
		23.8	7.14	0.67		1.31	
5	1700	1.2	0.36	0.72		1.41	
		9.4	2.82	0.51	0.56	0.99	1.10
		20.1	6.03	0.46		0.91	

Table 3.12: Total suspended solids levels November 6, 1991

Station	Time	Depth (ft)	TSS (mg/L)
Stn 1	0710	0.4	6.0
	1142	0.4	7.3
	1142	14	8.0
	1142	26.7	7.3
	1450	0.7	8.5
	1450	15.9	8.3
	1450	31.5	8.4
Stn 2	0755	0.5	11.0
	0755	15	9.2
	1200	1.0	5.2
	1200	13.6	5.6
	1200	26.5	7.6
	1525	0.4	9.1
	1525	10.0	9.3
	1525	20.0	9.2
Stn 3	0850	1.0	9.6
	0850	12.3	9.7
	0850	25.9	10.9
	1230	0.6	7.2
	1230	13.7	7.1
	1230	26.6	7.4
	1600	0.6	8.0
	1600	10.7	8.7
	1600	19.9	8.5
Stn 4	0933	1.0	10.0
	0933	14	10.0
	0933	28	13.0
	1300	1.0	5.6
	1300	15.6	7.5
	1300	29.4	7.6
	1630	1.0	8.5
	1630	12.3	8.8
	1630	23.8	8.9
Stn 5	1020	1.8	9.2
	1020	7.0	6.8
	1020	13.1	8.7
	1330	0.6	7.4
	1330	9.0	7.5
	1330	18.0	7.6
	1700	1.2	8.3
	1700	9.4	8.2
	1700	20.1	8.7
Stn 6	1050	0.2	5368
	1345	0.2	1070

Table 3.13: Physical and chemical parameters at Station 8, November 22, 1991

Station 8	Surface	Mid-Depth	Bottom
Time	T = 10.0		
	C = 85.3		
Z = 0.5 (0.15)	DO = 8.0		
	pH = 7.6		
	%S = 90.0		
	S = 35.9		

(N.B.) bracketted values are in metres

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth in feet (metres)

Table 3.14: Physical and chemical parameters at Station 9, November 22, 1991

Station 9	Surface	Mid-Depth	Bottom
Time	T = 10.2		
	C = 71.9		
Z = 0.5 (0.15)	DO = 8.0		
	pH = 7.7		
	%S = 90.0		
	S = 30.9		

(N.B.) bracketted values are in metres

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth in feet (metres)

Table 3.15: Physical and chemical parameters at Station 10, November 22, 1991

Station 10	Surface	Mid-Depth	Bottom
Time	T=10.0		
	C=89.9		
Z=0.5 (0.15)	DO=8.0		
	pH=7.6		
	%S=90.0		
	S=39.4		

(N.B.) bracketed values are in metres

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth in feet (metres)

Table 3.16: Physical and chemical parameters at Station 11, November 22, 1991

Station 11	Surface	Mid-Depth	Bottom
Time	T=10.0		
	C=78.0		
Z=0.5 (0.15)	DO=8.0		
	pH=7.7		
	%S=90.0		
	S=33.3		

(N.B.) bracketted values are in metres

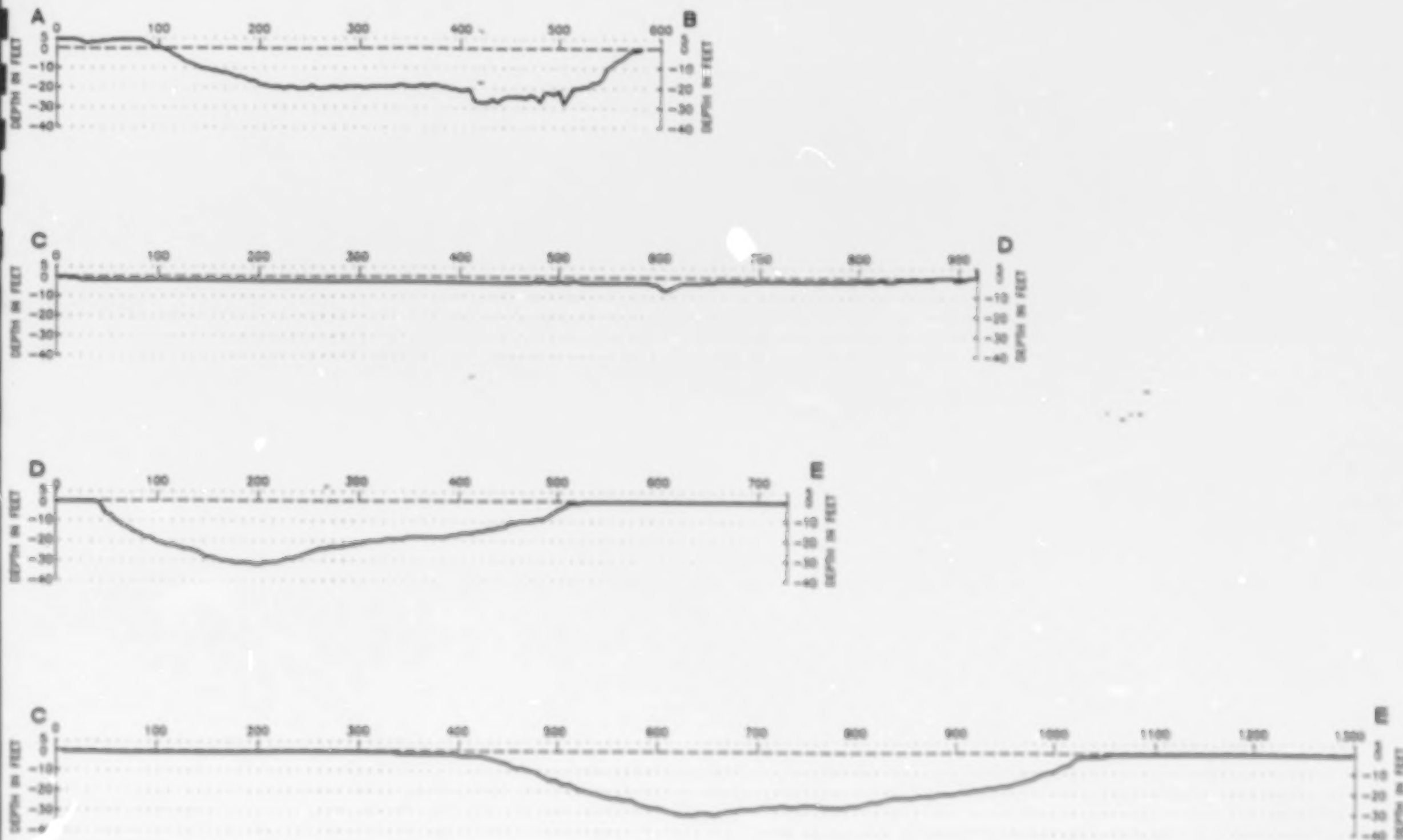
T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth in feet (metres)

Table 3.17: Physical and chemical parameters at Station 12, November 22, 1991

Station 12	Surface	Mid-Depth	Bottom
Time	T=9.95		
	C=88.9		
Z=0.5 (0.15)	DO=8.0		
	pH=7.6		
	%S=90.0		
	S=38.8		

(N.B.) bracketted values are in metres

T - temperature (°C)
 C - conductivity (mS/cm)
 DO - dissolved oxygen (mg/L)
 %S - percent oxygen saturation
 S - salinity (ppt)
 Z - depth in feet (metres)



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NOTES:
ELEVATIONS REFERENCED TO TIDE
BOARD AT PUGWASH GOVERNMENT
WHARF. SOUNDINGS IN FEET REDUCED
TO LOWEST NORMAL TIDE.

SCALE: 1" = 100' HORIZONTAL
1" = 10' VERTICAL
DATE: 91/12/16
DRAWN BY: D. BAYER
CHECKED BY:

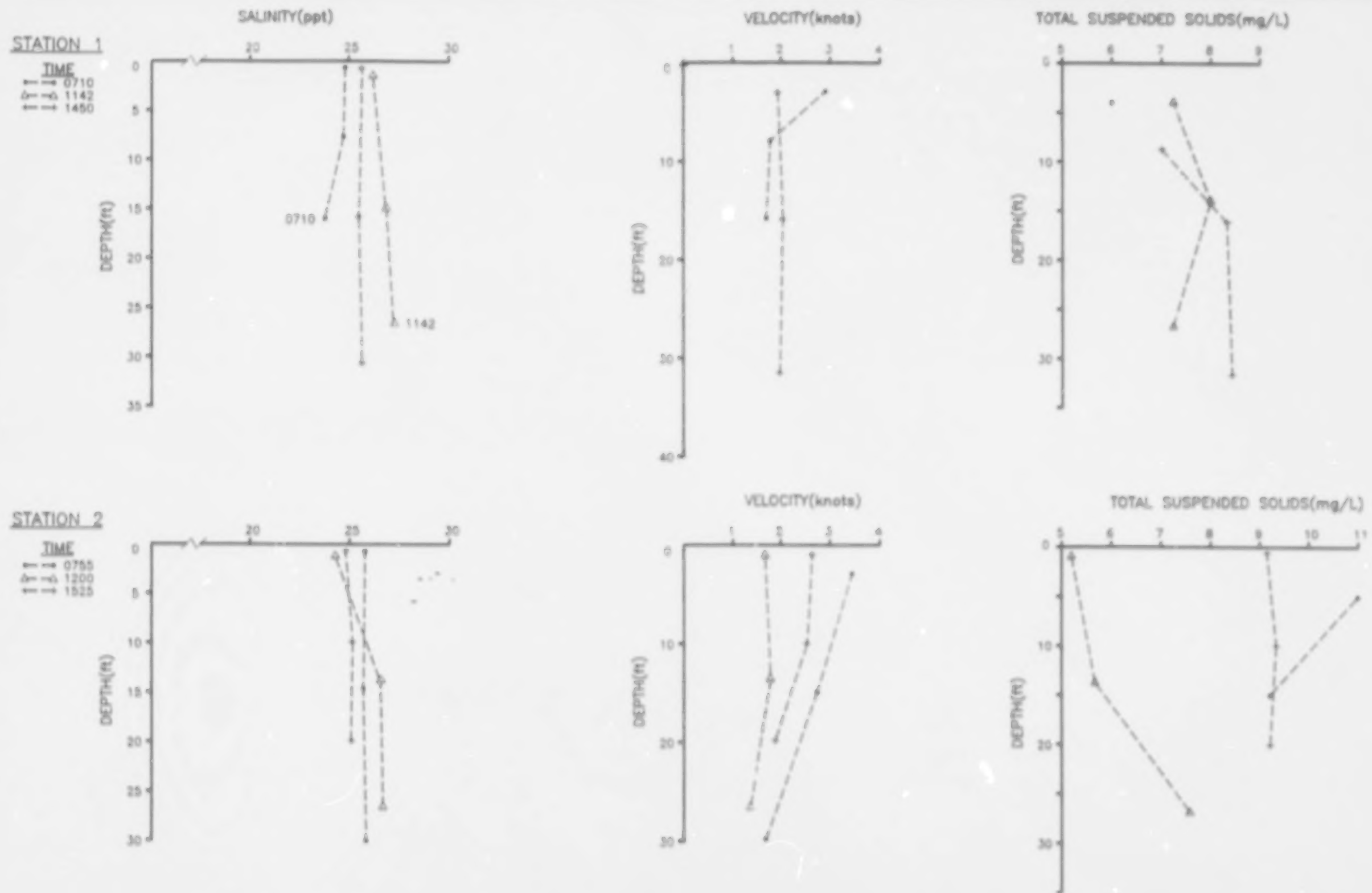
THE CANADIAN SALT COMPANY LIMITED

**EFFLUENT
CONTROL**

PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIA

**BATHYMETRY TRANSECTS
ACROSS THE PUGWASH
ESTUARY**

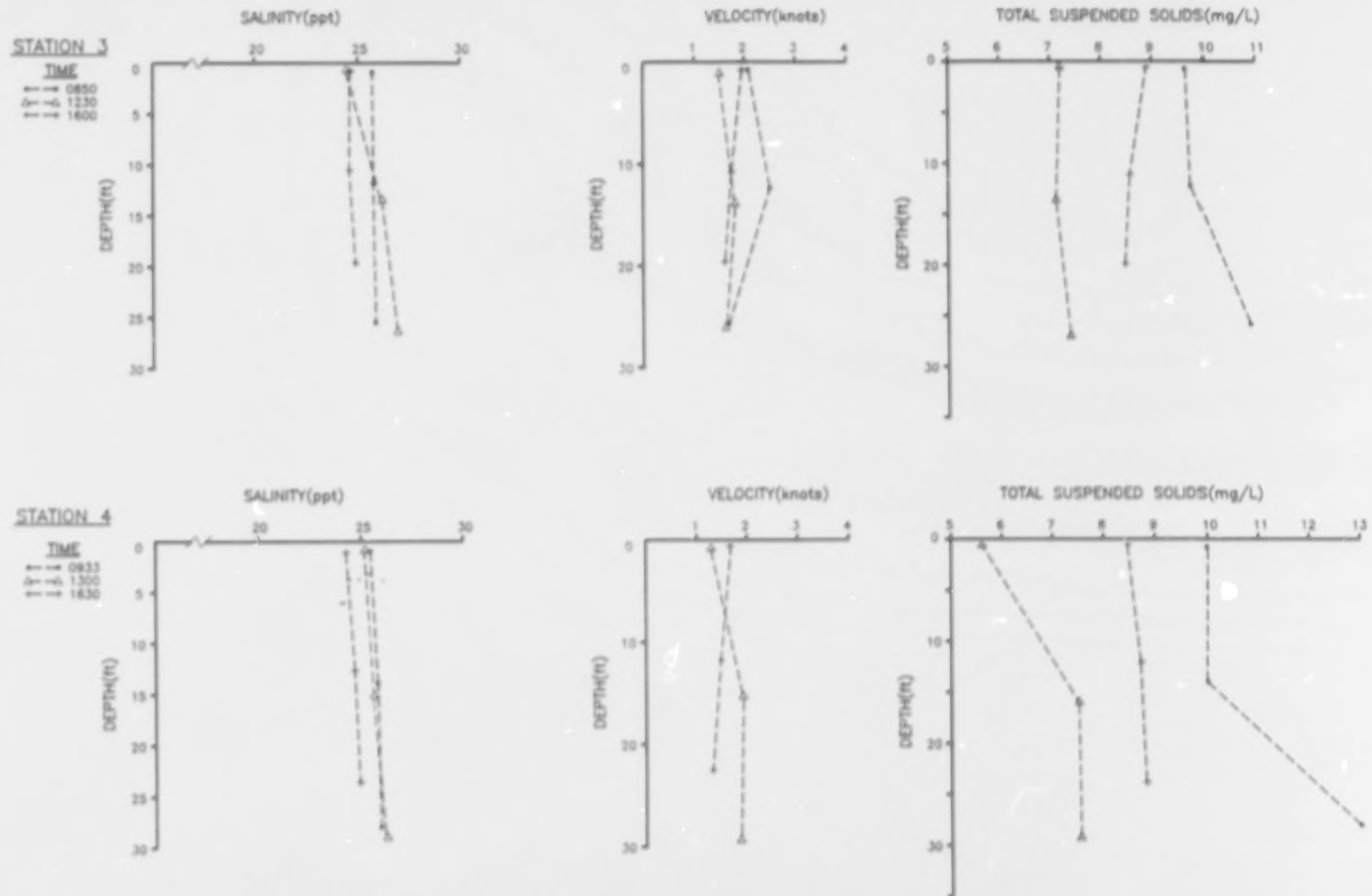
FIGURE 3.2



VERTICAL PROFILES OF SALINITY, VELOCITY AND SUSPENDED SOLIDS
 STATIONS 1 AND 2

1 foot = 0.3048 metres





VERTICAL PROFILES OF SALINITY, VELOCITY AND SUSPENDED SOLIDS
 STATIONS 3 AND 4

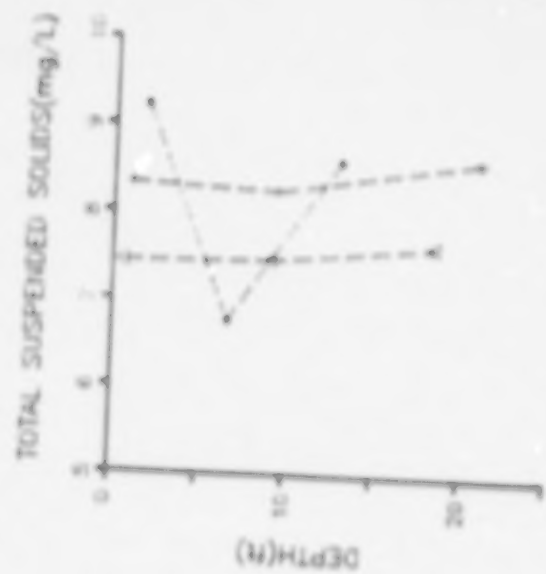
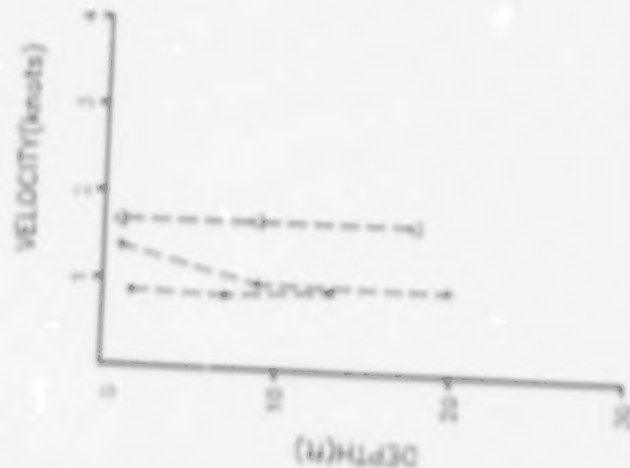
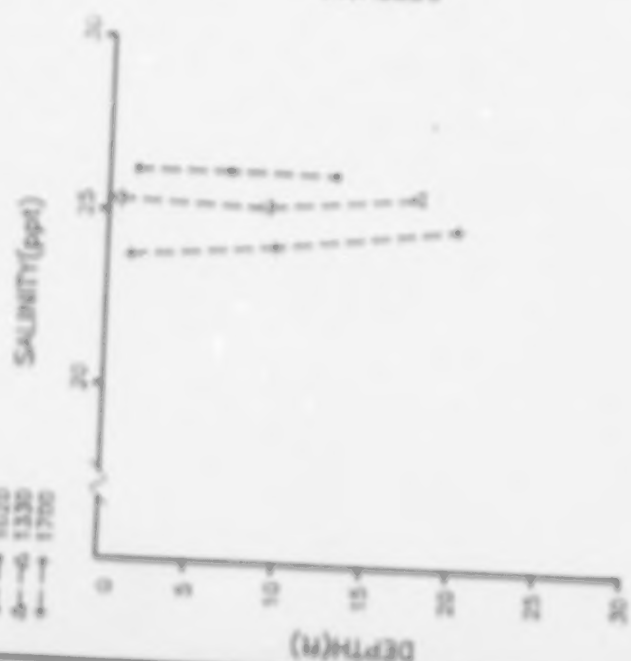
1 foot = 0.3048 metres



STATION 5

TIME

- 1620
- 1630
- 1640
- 1650
- 1700



1 foot = 0.3048 metres

VERTICAL PROFILES OF SALINITY, VELOCITY AND SUSPENDED SOLIDS STATION 5



4.0 PROPOSED MODIFICATIONS

4.1 Brine Storage Pond Overflow Diversion

The proposed new overflow arrangement is shown on drawing No.'s 7583-11 and 7583-12 in Appendix C. The excess brine is collected at a new overflow chamber located at the South-West corner of the pond and flows by gravity via a 200 mm (8 inch) pipe to Nellies Pond.

An alternative route discharging directly into the Deep Cover Tailings Pond was considered. This route was rejected because it offers no apparent technical advantage and would be more costly due to the obstacle presented by the CNR embankment. A modified alternative is to lead the pipeline directly to the existing stone culvert. This was rejected because the culvert is in very poor condition and any new work installed immediately adjacent will eventually be disrupted by either repair or demolition of the culvert.

On the proposed route, an intermediate drop manhole is provided to limit excavation depths. It also allows for better inspection and cleaning of the line. The outfall structure serves to protect the discharge end of the pipe, retain the surrounding earth and to avoid scouring of the immediate area in front of the discharge point. The proposed gabion construction is a well established method of controlling water flows and dissipating the velocity energy of the discharge. The construction also provides a relatively flexible and aesthetic solution requiring little or no maintenance.

4.2 Diversions of the Hotwell Discharges

The insoluble and undissolved material purges from the treatment tanks are to be directed for discharge to the Deep Cove area to fulfil the ECP. Currently these purges are released with the Hotwell sump overflow and discharged directly into the

Pugwash River. It has been suggested that generally 90% of the treatment purges are released from the Settlement tank.

4.2.1 General

The discharges which have caused environmental concern are the fine sediment wastes from the settling tank, rotorake and reactivator brine treatment processes. These wastes are all presently discharged into the drainage trench downstream of the Hotwell where they join the Hotwell discharge flows.

4.2.2 Options

There are only two viable options to deal with the sediment wastes.

1. Collect the wastes and pump them across the site to the waste sump at the dissolver. The existing Linatex pump at the waste sump has adequate capacity to deal with the extra flow. The wastes will therefore end up in the tailings pond.
2. Intercept the bulk of the wastes (90%) at the dissolver area by installing a new settling tank adjacent to the dissolver which would avoid transferring this proportion of the waste twice across the site before eventual disposal. The remaining (10%) of the waste is produced from the combined discharges of the reactivator & roto-rake. This would still have to be collected and pumped across the site to the waste sump in a similar manner to option (1), but requiring smaller dia pipeline & pump capacity.

The choice between the above two options comes down to balancing the smaller pumping requirement against the need to install a new settling tank.

From our discussions with the CSCL, the possibility of moving the existing settling tank has been discarded. It would be very disruptive to operations and the removal costs would not necessarily be much less than the cost of a new tank. It has therefore been established that if a new settling tank is erected at the dissolver the existing settling tank will remain to provide secondary settling treatment or merely as additional storage in the system.

4.2.3 Comparative Assessment

A task comparison of the two options is outlined below. This is of necessity very approximate but serves to indicate the relative difference between the two options. To determine the selected option a further cost exercise can be done if required.

Option 1 - Collect Wastes

- Diversion of pipework into existing sump under settling tank
- New slurry pump (approx 50 HP)
- Control system
- 150 mm (6") dia transfer pipeline (approx 220 m (720 ft))

Option 2 - New Settling Tank

- Diversion of pipework into existing sump under settling tank
- New slurry pump (approx. 7.5 HP)
- Control system
- 100 mm (4") dia transfer pipeline (approx 220 m (720 ft))
- New settling tank foundations
- New settling tank & support framework
- New transfer pump at dissolver (20 HP)
- New pipework & modifications at dissolver
- Re-siting propane tank

Option 2, New settling tank presents two significant disadvantages.

1. Providing a new settling tank will result in large costs not only for the tank itself but for the necessary modifications to the dissolver area.
2. A new slurry pump, controls and a pipeline are still required and although smaller, the costs are comparable. The pipeline cost is only reduced by the difference in material costs of the pipe & fittings, a small proportion of the total.

In addition we should point out that there is much less margin for error in the costs for Option 1 than Option 2. In particular the new foundations for the settling tank can not be properly assessed without proper physical soil investigation & scheme design.

4.2.4 Conclusion

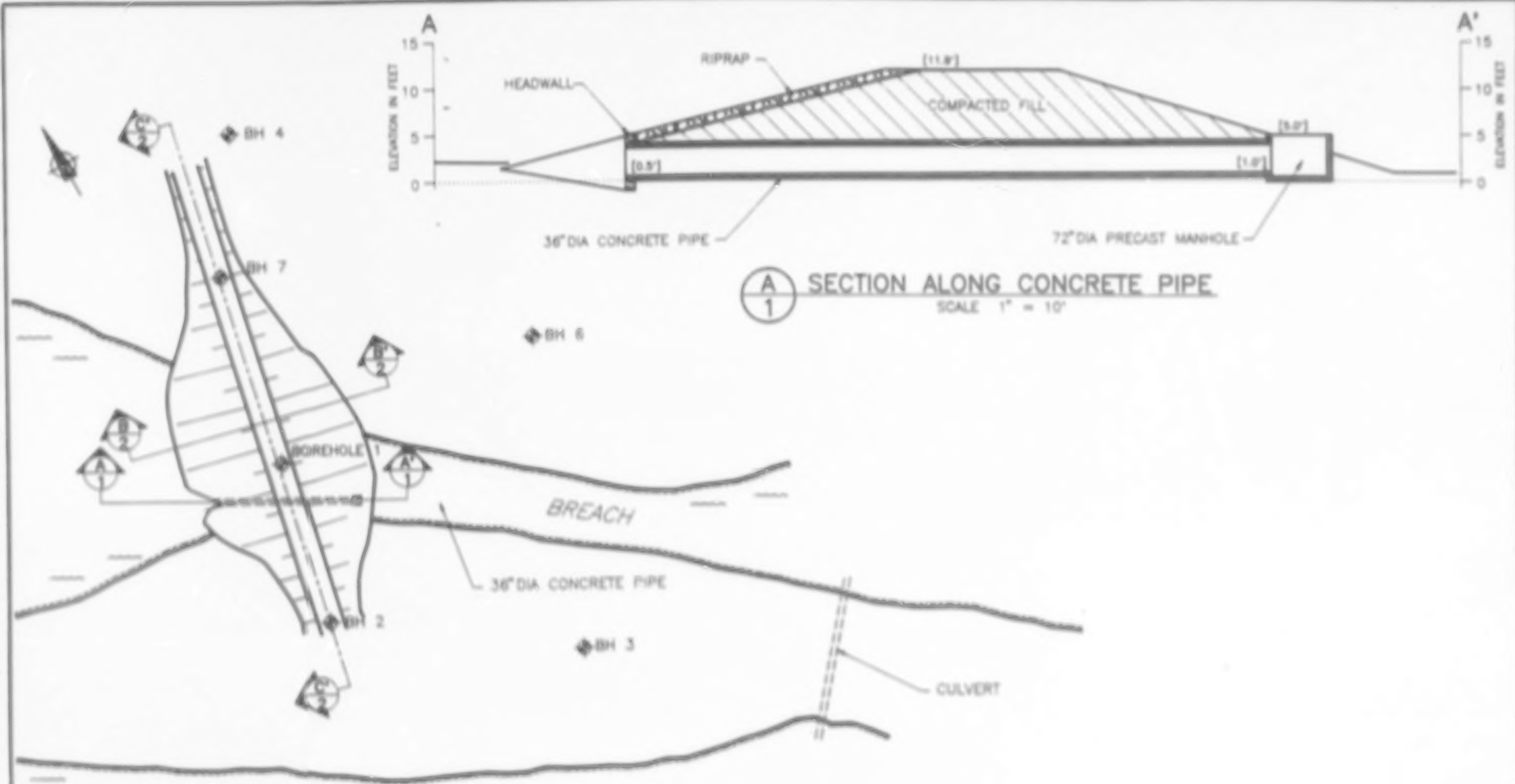
We recommend selection of Option 1 on the grounds of lower costs, relative simplicity and minimal disruption to operations.

4.3 Deep Cove Tailings Area

4.3.1 Breach Repair Design

The layout of the proposed dam required to repair the breach is shown on Drawing 7583-3. The location of the section of dam is defined by the line described by the two coordinates 16,661,274.7 N, 18,259,056.7 E, and 16,661,465.3 N, 18,259,096.1 E (coordinates are in feet). The origin of the chainage system, 0+00, is defined to be at the location 16,661,274.7 N, 18,259,056.7 E, which also corresponds to the location of BH 2 (Appendix B). This location and orientation of the dam was selected in





DESIGNED FOR REPORTING PURPOSES ONLY



Jacques,
Whitford and
Associates Limited

REFERENCE

SCALE: AS SHOWN
 DATE: 91/01/16
 DRAWN BY: D. BAYER
 CHECKED BY: [Signature]

CANADIAN SALT MINE COMPANY LIMITED

**EFFLUENT
CONTROL**

PUGWASH, CUMBERLAND COUNTY

**PROPOSED BREACH
REPAIR - PLAN AND
CROSS-SECTION**

FIGURE NO.

7583-3

order to minimize the quantities of earth moving required to repair the breach in the original retention dam.

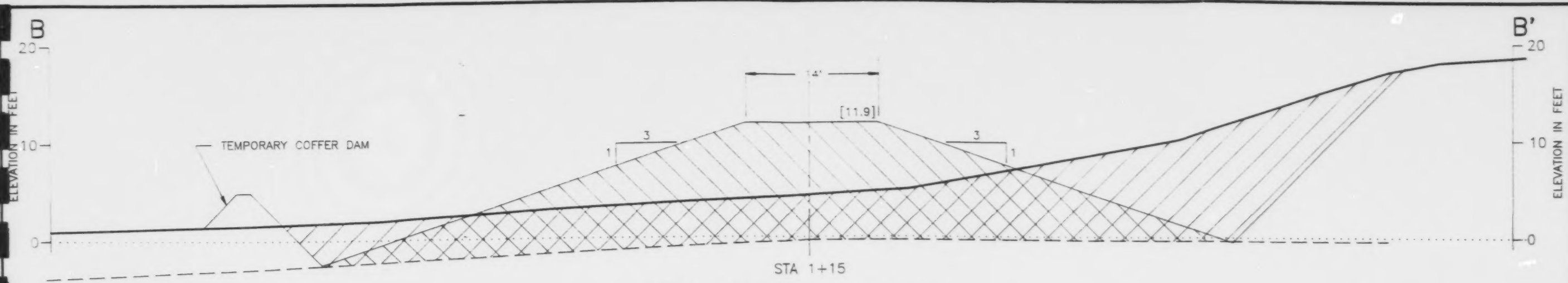
A typical longitudinal section and cross section of the proposed dam is shown on Drawing 7583-4. The design elevation of the crest of the dam is 3.6 m (11.9 feet) (Canadian Geodetic Datum). This corresponds to the design elevation of the original retention dam, and provides 1.2 m (4 feet) of freeboard above the highest recorded tide, according to information supplied by the Canadian Salt Company Ltd. The width of the crest of the dam is to be 4.3 m (14 feet), which allows for vehicle and equipment access across the completed dam.

A 900 mm (36 inch) pipe is to be installed through the base of the breach repair, aligned with the present breach, as shown on Drawing 7583-3. The invert of the pipe at the outfall is El. 0.15 m (0.5 ft.), and at the inlet structure is El. 0.3 m (1.0 ft). The top of the inlet structure, made up of a standard precast manhole section, is at El. 1.5 m (5.0 ft). The purpose of the pipe and inlet structure is to act as an emergency retention pond discharge in the event that the inflows to the pond cannot be handled by the normal discharge and pond levels exceed El. 1.5m (5.0 ft). In addition, the inlet structure is easily accessible so that service and maintenance can be accomplished.

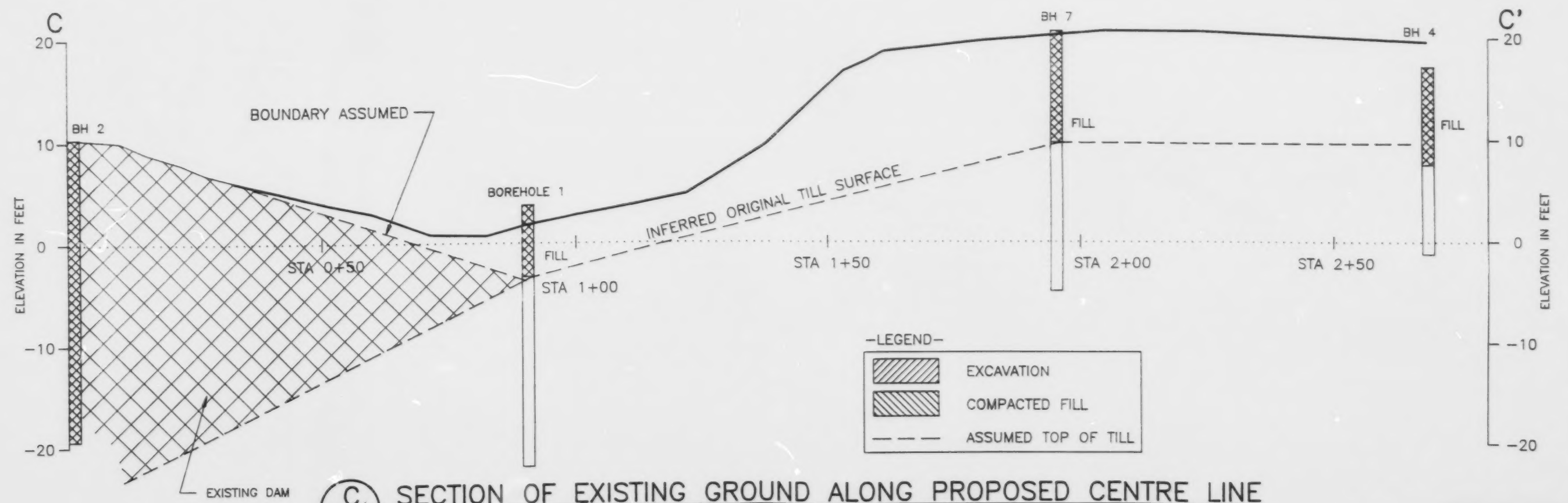
The drawings and cost estimates have been prepared using a concrete pipe as a least cost option. We understand that asphalt coated corrugated still pipe may be favoured by the personnel, and can be substituted at a probable additional cost.

The side slopes of the dam section are to be constructed at 3 horizontal : 1 vertical. This slope inclination is specified for ease of construction and in order to satisfy the requirements of slope stability, while at the same time minimizing excavation and fill quantities. Flatter slopes are permissible, but at the expense of increased excavation and fill quantities.





B
1 SECTION — TYPICAL
SCALE 1" = 10'



C
1 SECTION OF EXISTING GROUND ALONG PROPOSED CENTRE LINE
SCALE HOR. 1" = 20' VER. 1" = 10'

—LEGEND—

	EXCAVATION
	COMPACTED FILL
	ASSUMED TOP OF TILL

ISSUED FOR REPORTING
PURPOSES ONLY



Jacques,
Whitford and
Associates Limited

REFERENCE

SCALE : AS NOTED
DATE : 92/01/14
DRAWN BY : J.M.CORBETT
APPROVED BY :

CANADIAN SALT MINE COMPANY LIMITED
**PROPOSED
COFFER DAM**
PUGWASH, CUMBERLAND COUNTY, N.S.

**PROPOSED
BREACH REPAIR
CROSS-SECTIONS**

DRAWING NO.
7583-4



Cofferdams should be constructed prior to construction around the base area of the dam to prevent the ingress of tidal water and to prevent the base of the excavation from becoming wet and soft. It may be necessary to also construct a sump within the excavation area from which any seepage water can be pumped.

Existing deleterious overburden mine wastes are to be excavated from the foundation of the proposed dam. Unacceptable foundation materials include loose or soft fills, soils containing significant quantities of organics, permeable soils, or soils and fills containing soluble minerals. As revealed by the geotechnical investigation, acceptable foundation materials include undisturbed till, existing compacted dam fill derived from native till.

Fill material for the construction of the dam shall consist of a suitable cohesive impermeable soil. It is understood that the existing retention dam was constructed using till from a borrow pit located on mine property east of the eastly end of the dam. This fill was sampled in the existing dam in Boreholes 2 and 3, and based on visual examination and limited laboratory testing (Appendix B) appears to be a suitable fill material. It is assumed that sufficient quantities remain in the borrow pit for the construction of the dam to repair the breach.

Fill material placed for the construction of the section of dam to repair the breach should be placed in horizontal lifts of no more than 300 mm (12 inches) and compacted to 95 percent of Standard Proctor Density. Particles larger than 300 mm (12 inches) should be removed. Care should be exercised in compacting the initial lifts to ensure that the underlying soils are not disturbed and softened.

The face of the dam adjacent to the river (i.e., the downstream face) is to be protected by a 0.6 metre (2 foot) thick layer of riprap. The riprap should extend from the crest of the dam down to El. -0.91m (-3ft), and is recommended to consist of sound rock material conforming to the following gradation:

Recommended Riprap Gradation

<u>Size (mm)</u>	<u>% Finer</u>
400 (16 in)	100
250 (10 in)	75 - 50
150 (6 in)	0 - 5

In order to prevent the dam fill material from being washed through the riprap, a layer of filter fabric should be placed between the dam fill and the riprap. The filter fabric should have properties equivalent to Mirafi P350. As an alternative to using filter fabric, a graded granular filter layer may be used.

4.3.2 Modifications to Existing Dam

The crest of the existing dam has elevations ranging from about 3.62 to 2.63 metres (11.88 ft. to 8.64 ft). The entire crest should be filled to El. 3.63 metres (11.9 ft) over a width of at least 4.3 metres (14 ft). If the crest of the dam is to be used for a haul road for the construction of the breach repair, it is recommended that the raising of the crest of the dam be completed prior to the beginning of construction of the breach repair. The fill material used for this purpose and its compaction should be the same as that used for the breach repair.

In order to improve the trafficability of the dam crest, a 300 mm (12 inch) thick course of granular material may be placed over the width of the dam crest. This granular material should conform to the specification of Nova Scotia Department of Transportation Class B Granular. If it is found that vehicle traffic ruts this wear layer unacceptably during the course of construction of the breach repair, additional thickness of granular material may be added. The granular wear layer may also be added to the crest of the breach repair, after construction.

4.3.3 Tailings Deposition Scheme

Previous sections of the report have described the nature and basic chemical characteristics of the solid wastes to be disposed of as tailings. For the purposes of this proposed deposition scheme, it has been estimated that about 90,000 tonnes (99,180 tons) of dry solids per year will require storage. The tailings solids are estimated to consist of about 93% anhydrite (CaSO_4) and 7% salt (NaCl). Analyses of several samples of the waste solids indicates grain size distributions as shown on Figure 4.1. Based on the relative proportions of settlement tank solids purged on a regular basis and the waste solids from the dissolver, a grain size distribution of a "blend" has been inferred and is also shown on Figure 4.1.

This section discusses a typical tailings deposition scheme and consists of four stages. The four stages and typical cross sections of the resulting tailings deposit are shown on the appended drawings, as noted in the following paragraphs. The tailings deposition scheme is based on the closure of the breach with a new dam. The proposed tailings deposition scheme also includes a monitoring programme in order to ensure that the stability of the tailings deposit is maintained and that the scheme can be safely carried out as proposed.

The CSCL also have indicated that some tonnage could be used for maintenance and site repairs purposes. The gypsum-anhydrite waste solids would be used to fill in the solution cavities and collapses which develop within the salt backfilled areas of the mine peninsula.

4.3.3.1 Low Height Perimeter Retention Dyke

After the closure of the breach has been completed, the deposition scheme requires that a low height perimeter retention dyke be constructed at the perimeter of the newly proposed tailings pond. This dyke should be constructed by excavating and moving existing tailings in order to separate the pond (and channel) from the main

solids accumulation area. The height of this dyke is only required to be about 1 to 1.3 metres (3 to 4 feet) in most areas (to el. 2.1 metres (7 feet)). This dyke will serve two main purposes:

1. to prevent the tailings pond from backing up onto the solids deposition area during high water periods, and
2. to prevent liquid and solids flows from the tailings discharge line from flowing directly into the pond, by directing these flows to the upstream end of the pond. This will allow more complete deposition of the solids onto the intended solids deposition flats.

An overall side slope of 4 horizontal to 1 vertical is recommended for the configuration of this perimeter retention dyke. As the spigotting of tailings is carried out over time, it will be necessary to maintain a perimeter dyke height of about 0.6 to 1 metre (2 to 3 feet), as the tailings solids collect and are deposited on the upstream face.

Construction of the perimeter retention dyke can likely be facilitated by a single dozer, which can accomplish excavation, placement and compaction of the tailings to form the required structure. Tailings should be placed in lifts of about 300 mm (12 inches) prior to compaction with the dozer used for spreading.

4.3.3.2 Stage 1 - Conventional Spigotting

Stage 1 will consist of conventional spigotting of the tailings into the Deep Cove tailings area as is presently being done, with the addition of flows from the Hotwell Discharge, as discussed previously.

Our calculations assume that the tailings solids will flow with subsequent deposition occurring at a slope of about 1.5%, based on measurements of the existing tailings

flats. Drawing 7583-5 shows the proposed configuration of the tailings area when the tailings elevation at the pond is about 10 feet.

To achieve this configuration it will be necessary to move the discharge pipe both with respect to location and elevation over the time frame required. The maximum elevation of the tailings solids is 4.6 metres (15 feet). Based on this scheme, it has been calculated that approximately 99,120 cubic metres (3.5 million cubic feet) of tailings can be accommodated. This corresponds to about 174,000 tonnes (191,748 tons) of dry tailings. At 90,000 tonnes (99,180 tons) per year, this first stage will accommodate approximately 1.9 years of tailings.

This method of discharge and solids deposition could be extended to accommodate several more years of tailings production. This would, however, require modification of pump capacity and pipelines, since the ultimate elevation required to pump to would be about 18 metres (60 feet). The corresponding final elevation head would be about 14 metres (45 feet), which would require a substantial pump capacity.

4.3.3.3 Subsequent Stages

Stages 2 to 4, inclusive, are essentially similar and will include continued conventional spigotting with stacking of the previously deposited tailings. The designation of three such stages is used for typical scheduling purposes and the actual construction sequence is flexible to allow modification.

Stage 2 involves the excavation and placement of the previously deposited tailings in the area shown on Drawing 7583-6. The ultimate elevation proposed for this stage is 18 metres (60 feet). This configuration will accommodate an additional 161,400 cubic metres (5.7 million cubic feet) of tailings solids, for a total of about 260,500 cubic metres (9.2 million cubic feet). This corresponds to about 456,000 tonnes, or 5.1 years tailings production.

7
Stage 3 will utilize a smaller area adjacent to the pond, and in a similar fashion and a final elevation of 18 metres (60 feet), an additional 93,500 cubic metres (3.3 million cubic feet) of storage is available, for a total of about 354,000 cubic metres (12.5 million cubic feet). This corresponds to about 620,000 tonnes (683,240 tons) of tailings, or 6.9 years production.

Stage 4 is a small area adjacent to the new dam and will accommodate an additional 28,300 cubic metres (1.0 million cubic feet), adding 0.6 years storage, for a total of about 7.5 years.

4.3.3.4 Drainage of Tailings Deposit

During all stages of tailings deposition and stacking, it will be necessary to ensure that a positive gradient exists towards the perimeter drainage channels or to the low height perimeter dyke and on to the tailings pond. This is indicated on Drawings 7583-5 and 7583-6.

4.3.4 Tailings Pond and Channel

The tailings pond is proposed to occupy the deeper east area of Deep Cove, as shown on Drawings 7583-5 and 7583-6. Nellies Pond will continue to be drained through the new tailings pond. The normal operating pond level has been established at elevation 1.34 metres (4.4 feet), with effluent discharge from the pond controlled by the existing structure, as described in a subsequent section. The structure will require minor modifications, as will be discussed.

The surface area of the pond at an elevation of 1.34 metres (4.4 feet) is about 17,650 square metres (190,000 square feet), with a corresponding volume of about 700,000 cubic feet. The maximum normal depth will be about 2.0 metres (6.4 feet).

In order to allow for possible discharge of tailings effluent via the new closure dam, a channel adjacent to the existing dyke will have to be established. It is expected that some minor dredging or deepening of this channel will be required in order to provide a sufficient depth. The channel should be dredged to the elevation of 0.0 metres (0.0 feet) to reduce the effects of scour of the channel bottom during high flow periods.

In the event that dissolution of the side slopes of the pond and channel, which will be constructed with tailings, occurs, provision will have to be made for incorporating protection. Riprap may be considered and it should be of nominal 150 mm (6 inch) rock size placed to a thickness of 300 mm (12 inches). The protective layer should extend from an elevation of 0.6 metres (2 feet) below normal pond level of 1.34 metres (4.4 feet) to an elevation of 0.6 metres (2 feet) above expected high water level of about 1.8 metres (6 feet) (ie. from about elevation 0.6 to 2.4 metres (2 to 8 feet)). A synthetic filter fabric should be placed between the tailings and the riprap to prevent the loss of tailings solids through the coarse rock. Alternatively, other means of protection such as straw bales placed on the slopes and anchored may suffice.

4.3.4.1 Primary Outflow Control Structure

The proposed outflow control structure will consist of the existing culvert system which exists at the south end of the Deep Cove tailings area. This structure presently consists of a 180 cm (72 inch) diameter CSP riser with flows controlled by a 760 mm (30 inch) high by 600 mm (24 inch) wide opening fitted with a one-way flow device. The device is intended to prevent inflows to the tailings area when the tide levels are higher than pond levels. Photo No. 4.1 shows the existing control structure. The outflows from the structure are transmitted beneath the existing perimeter dyke via an 25 metre (80 foot) long, 760 mm (30 inch) diameter culvert.

The minimum elevation of the opening is presently about 0.67 metres (2.2 feet). In order to provide a normal operating pond level of elevation 1.34 metres (4.4 feet), the opening will have to be modified such that the minimum level is at elevation 1.1 metres (3.5 feet). The normal tailings discharge flows of 4.9 cfs (0.14 m³/s) have been used to establish these levels. This will require minor modification of the flashboards which can be installed in the guide channels of the riser. The same opening size as presently exists can be maintained.

We have not undertaken a study of the integrity of the existing 760 mm (30 inch) culvert beneath the existing retention dyke. It has been assumed that the construction of this system was as indicated on Canadian Rock Salt Company Limited Drawing No. PR-75-1, dated April 1975. As such, it should be adequate for the intended use.

Because the normal and high water levels in the pond will be higher than initially designed for, it will be necessary to provide protection to the headwall and existing retention dyke. Erosion of the dyke embankment is evident and is illustrated on Photo 4.1. Protection can be provided using a 300 mm (12 inch) thick layer of riprap consisting of nominally 150 mm (6 inch) size.

4.3.4.2 Outflow Structure

Another outflow structure exists which could transmit flows beneath the existing retention dyke, south of the breach area, as shown on Drawing 7583-2. Field examination suggests that this structure has settled and has become partially filled with sediment and may be damaged. This structure must be plugged or capped permanently to prevent unwanted outflows from occurring in this area, or retained as an overflow structure.

4.3.4.3 Hydraulic Performance

The hydraulic capacity of the modified primary outlet control structure has been examined using the 100 year/24 hour storm event occurring over the Deep Cove area as well as the area draining to Nellies Pond. Based on this event, a base flow of 0.14 m³/s (4.9 cfs) from the tailings discharge and the outlet hydraulics of the system, the maximum pond level that will be reached is about elevation 1.86 m (6.1 feet). In the event that very high tides occur simultaneously, which will restrict the outlet hydraulics somewhat, the maximum pond level would be about elevation 2.13 metres (7 feet).

4.3.4.4 Secondary Outlet Control Structure

A secondary outflow control structure has been incorporated into the design of the closure dam, and has been discussed in Section 4.3.1. The minimum elevation of the structure will provide a normal operating pond level of about 1.67 metres (5.5 feet), for a resulting pond area and volume of 24,150 square metres (260,000 square feet) and 26,200 square metres (925,000 cubic feet), respectively, assuming that the primary structure is closed.

4.3.4.5 Suspended Solids Control

The sedimentation potential of the pond has been assessed for an average normal tailings discharge rate of about 0.14 m³/s (4.9 cfs), over a 24 hour period. Based on Stokes Law and the physical properties of the solids and liquid portion of the effluent (ie. specific gravity, viscosity and temperature), it has been calculated that for the pond size as given above, the residence time is about 40 hours. The corresponding minimum particle size that will theoretically settle to the bottom of the pond is about 0.005 mm diameter. The calculations include a safety factor to account for disturbing forces such as short circuiting and irregularities of the sedimentation basin shape.

Based on the grain size distribution of the tailings solids (Figure 4.1), a basin efficiency of about 99.5% is indicated. Stated another way, in excess of 99.5% of all solids will be trapped prior to discharged, since less than 0.5% of the gradation has particles less than 0.005 mm diameter. The actual efficiency is expected to be even more since the design allows for a considerable amount of overland flow, which will trap additional particles.

4.3.5 Recommended Monitoring

A limited monitoring program for effluent quality is recommended to be performed throughout the life of this deposition scheme.

4.3.5.1 Effluent Quality

Effluent samples will have to be analyzed for suspended solids in order to verify the adequacy of the design. While this will be a requirement of the NSDOE as part of the compliance monitoring, it is important to recognize that if departures from the normal levels of solids discharge occur, a modification to the design or operating procedures may be indicated. Additionally, should solids levels be consistently below the acceptable levels, a reduction in pond size, for example, may be considered, thereby providing additional storage capacity within the tailings area for solids storage.

4.3.5.2 Pond Size Reduction

During the initial years of operation, it is recommended that the sediment accumulation in the pond be monitored. A reduction in pond volume will ultimately reduce the sediment capture efficiency. This may require periodic dredging to restore the pond to its design configuration. It may also indicate required modifications to the tailings deposition scheme to reduce the rate of sediment accumulation.

4.3.5.3 Tailings Accumulation

It will be of benefit to monitor the accumulation of tailings solids. This will verify the assumptions made regarding the solids accumulation rates and resulting slopes. Surveying on an annual basis should be considered and the data can be compared to the existing survey, and used to compute actual tailings volumes.

4.3.5.4 Stability of Tailings Deposit

The structural integrity of the tailings deposit will have to be monitored as it is being constructed. The deposition scheme has assumed that the side slopes will be stable at 4:1. This must be verified by obtaining data to establish the *in situ* shear strength and water table position of the deposit. It is recommended that this be carried out approximately two years into the deposition scheme, before the deposit becomes excessive in height.

4.4 Analysis of Effluent Discharge

Prepared by ASA Consulting
Summary of Findings

The oceanography of Pugwash Harbour in the area near the salt mine was considered using collected data (Appendix D). Currents and water levels were observed over a period of 13 hours. In general, the area is dominated by the tides. Conditions in the estuary are characterized by large tidal currents.

The analytical modelling results are also presented. The analytical modelling considered a shore discharge through a culvert, a single port diffuser and a multi-port diffuser. The shore discharge that was considered was located in the main River channel. Estimates of the resulting brine excess concentration in the river from the

shore outfall met the stated objectives of 10% of ambient within 300m from the outfall. The other outfalls also met the stated objectives.

Numerical modelling estimates of the excess brine concentration were determined for the shore discharge which is proposed from the existing culvert structure. The numerical modelling estimates of excess concentration ranged up to about 20 ppt (parts per thousand) at high tide near the outfall. During high tide, the small embayment where the discharge culvert is located experiences the maximum excess concentration due to the shallow nature of the embayment. However, conditions at other stages of the tide cycle are typically less than 2 ppt. In all estimates presented, the excess concentration drops to less than 2 ppt within 200 m from the contact point of the brine effluent and the river water.

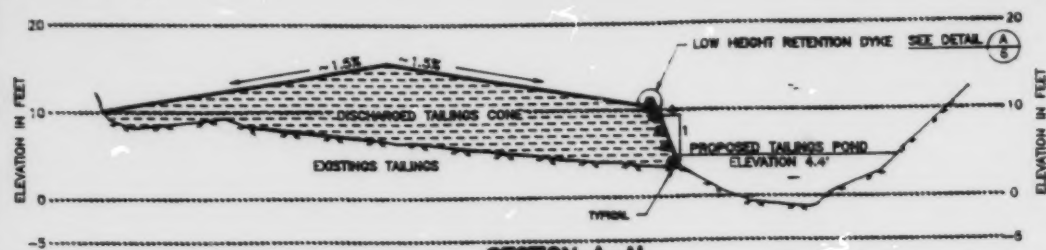
The existing culvert structure is adequate to disburse the effluent into the Pugwash estuary, with minimal environmental impact.

The full report prepared by ASA Consulting is attached as Appendix D.

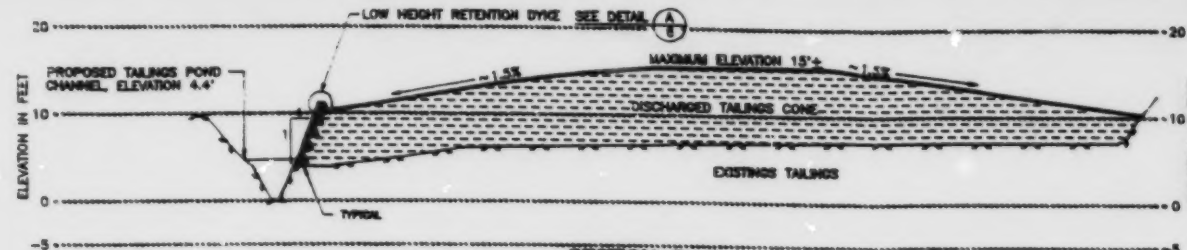


Photo 4.1 PRIMARY OUTFLOW CONTROL
STRUCTURE LOOKING WEST





SECTION A-A'
SCALE HOR. 1" = 200', VER. 1" = 20'

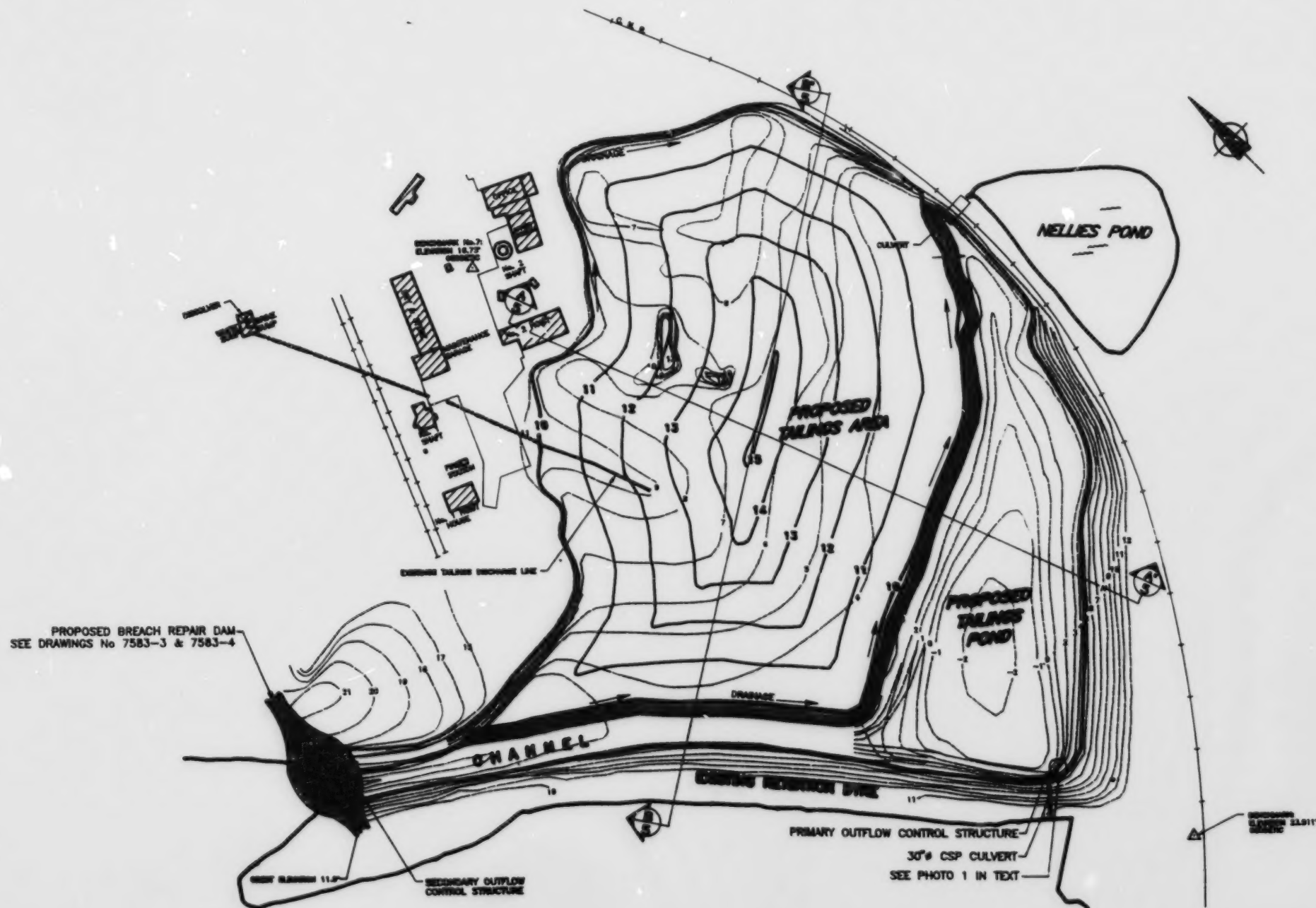


SECTION B-B'
SCALE HOR. 1" = 200', VER. 1" = 20'

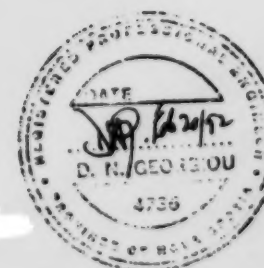
THE CANADIAN SALT COMPANY LIMITED
1000 WEST 10TH AVENUE
EDMONTON, ALBERTA T6P 0E6

LEGEND:

- PERMANENT BUILDING
- RAILWAY LINE
- EXISTING CONTOURS IN FEET
- PROPOSED CONTOURS IN FEET
- DRAINAGE



STAGE 1 TAILING DISPOSITION PLAN
SCALE 1" = 200'



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DATE	02/01/79	BY	D. N. GEORGIU
CHECKED		DATE	
DESIGNED		DATE	
DRAWN		DATE	
IN CHARGE		DATE	

THE CANADIAN SALT COMPANY LIMITED

**EFFLUENT
CONTROL**

PUGHASH, CLAMBERLAND COUNTY, NOVA SCOTIA

**STAGE 1 - TAILINGS
DEPOSITION AND DETAILS**

Jacques, Whitford and Associates Limited
CONSULTING ENGINEERS AND ARCHITECTS

02/01/79 AS NOTED BY D. BAYEN



7583-5

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LEGEND:

PERMANENT BUILDING

RAILWAY LINE

20' PROPOSED STAGE 2 CONTOURS IN FEET

20' PROPOSED STAGE 3 CONTOURS IN FEET

20' PROPOSED STAGE 4 CONTOURS IN FEET

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THE CANADIAN SALT COMPANY LIMITED

EFFLUENT CONTROL

FLORISSA, CAMBERLAND COUNTY, NOVA SCOTIA

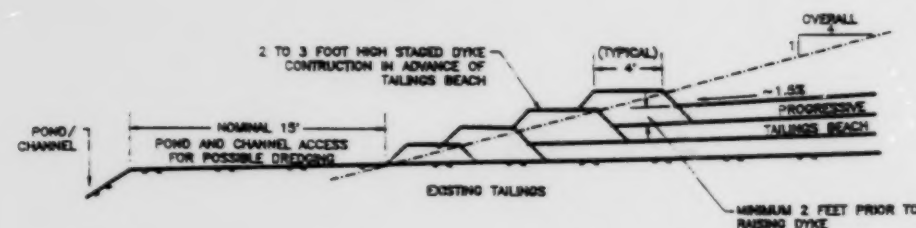
STAGE 2, 3 AND 4 TAILINGS DEPOSITION AND DETAILS

Jacques, Whitford and Associates Limited
CONSULTING ENGINEERS AND ARCHITECTS

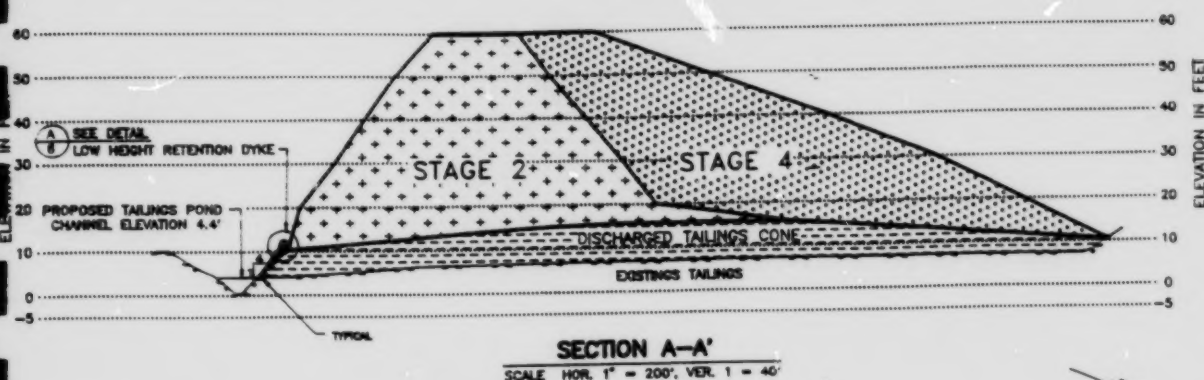
DATE: 92/01/28 DRAWN BY: AS NOTED CHECKED BY: D. BAYER



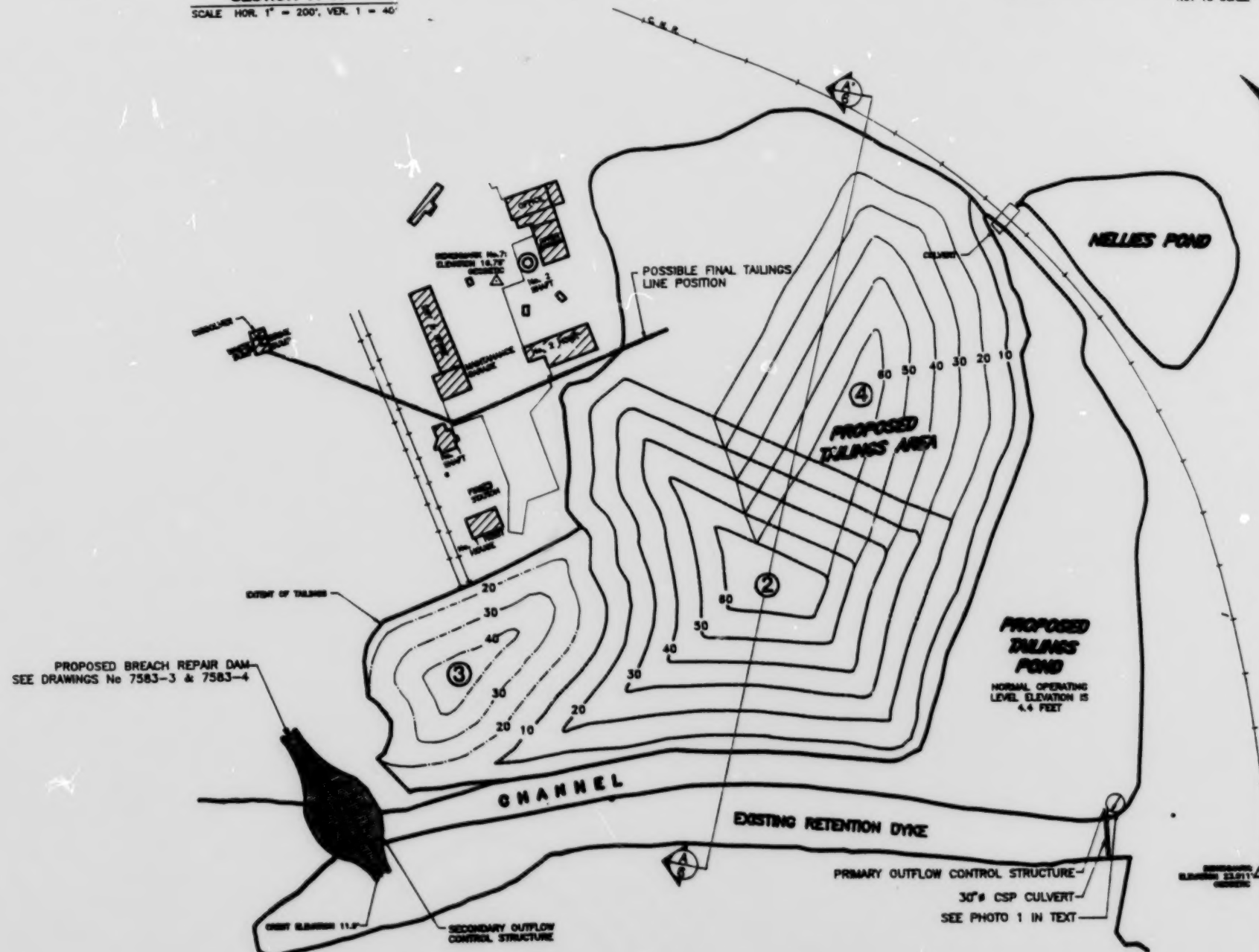
7583-6



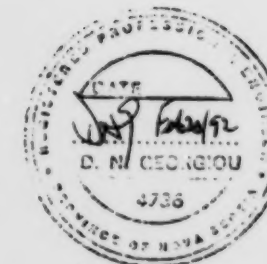
DETAIL A - LOW HEIGHT PERIMETER RETENTION DYKE
NOT TO SCALE

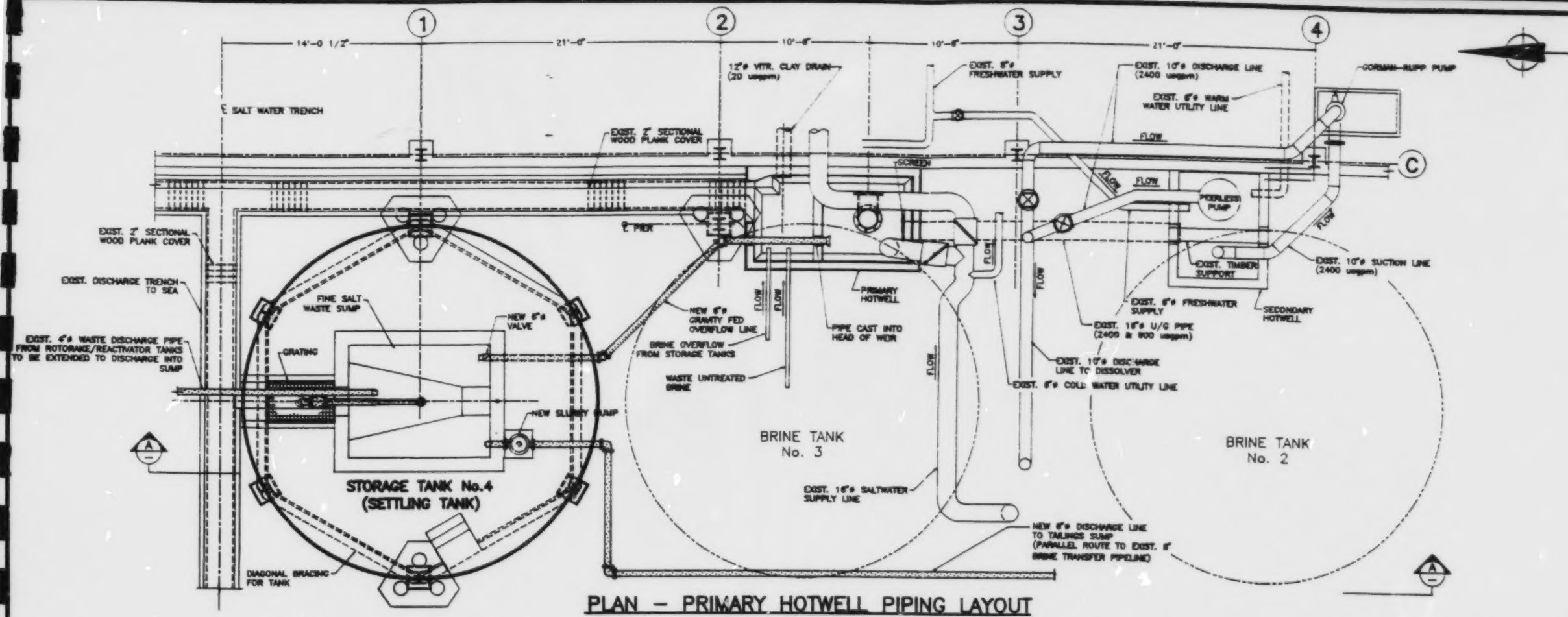


SECTION A-A'
SCALE HOR. 1" = 200', VER. 1" = 40'



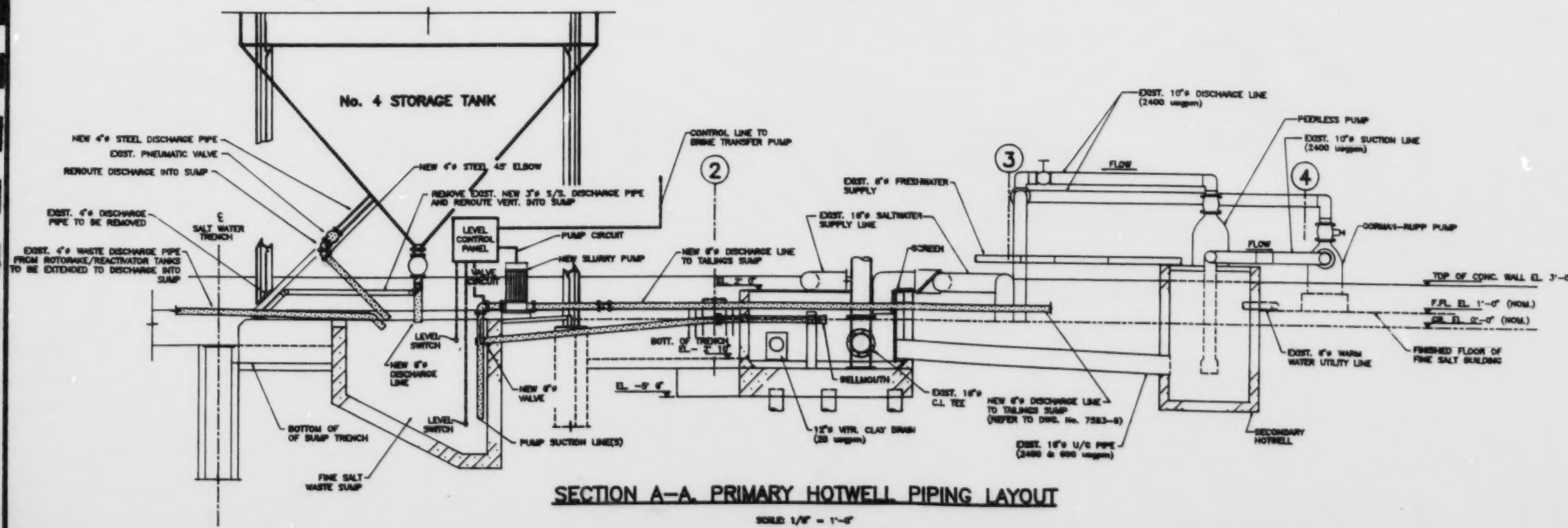
STAGE 2, 3 & 4 TAILINGS DISPOSITION PLAN
SCALE 1" = 200'





PLAN - PRIMARY HOTWELL PIPING LAYOUT

SCALE: 1/8" = 1'-0"



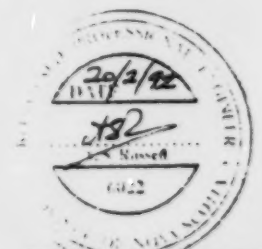
SECTION A-A. PRIMARY HOTWELL PIPING LAYOUT

SCALE: 1/8" = 1'-0"

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NOTES:

1. THIS DRAWING IS SOLELY INTENDED TO ILLUSTRATE METHOD OF RE-ROUTING SLURRY WASTES FROM BRINE TREATMENT TANKS. DIMENSIONS AND ELEVATIONS ARE APPROXIMATE OR BASED ON RECORD DRAWINGS. READ IN CONJUNCTION WITH REPORT SECTION 4.2 (OPTION 1). LOCATION AND DETAILED ROUTING OF EQUIPMENT TO BE RESOLVED ON SITE.
2. CONTROL SYSTEM REQUIRED FOR:
1) LEVEL CONTROL OF LIQUID IN SUMP.
2) SLURRY PUMP ON/OFF.
3) BRINE TRANSFER PUMP ON/OFF.
4) VALVE THROTTLING ON PIPE LEADING FROM WEIR OF HOTWELL (e.g. MECHANICAL FLOAT VALVE)
3. SLURRY PUMP: FLOW 800 USGPM AGAINST 90 FT. HEAD. (BASED ON USE OF 6" HOPE DISCHARGE LINE AND ALLOWING APPROX. 50 FT. FRICTION HEAD LOSSES.)



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APP'D. BY	REVISION	DATE

CANADIAN SALT COMPANY LIMITED

EFFLUENT CONTROL

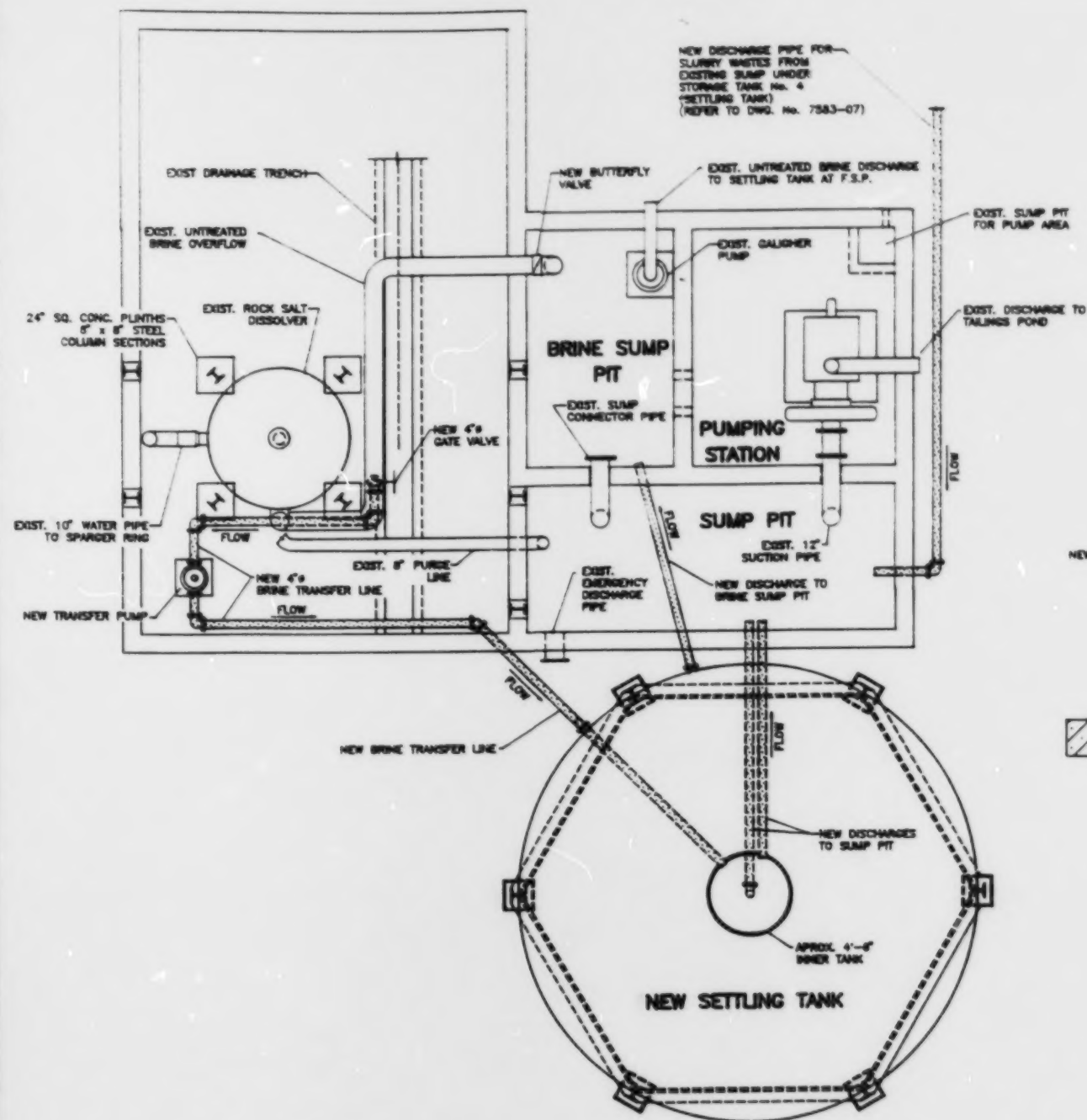
PUGHRIE, CUMBERLAND CO., NOVA SCOTIA

HOTWELL DISCHARGES PROPOSED ALTERATIONS

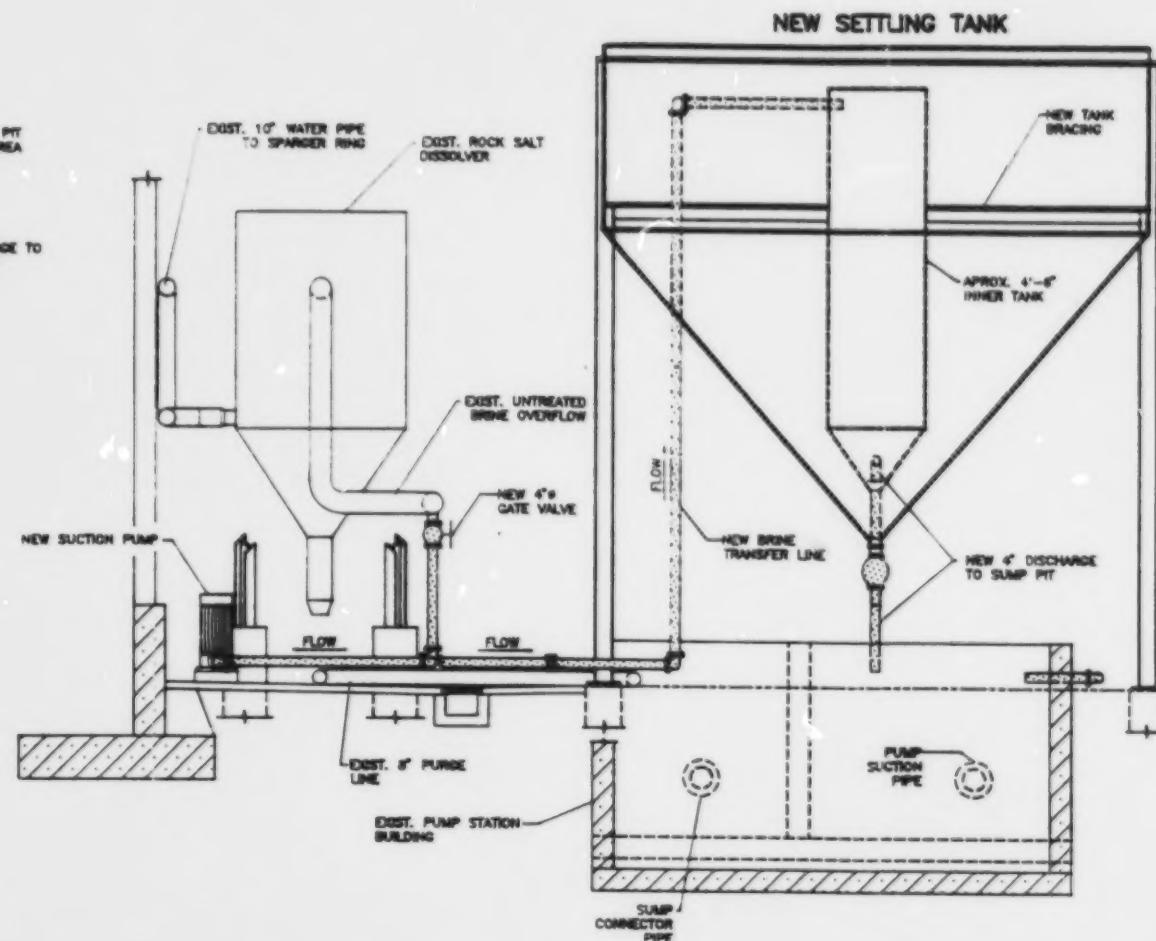
Jacques Whitford Environmental Limited
CONSULTING ENGINEERS AND SCIENTISTS

DATE	SCALE	DESIGNED BY
92/31/01	1/8" = 1'-0"	P.J.BOO





PLAN
SCALE 1/8" = 1'-0"



ELEVATION
SCALE 1/8" = 1'-0"

THIS DRAWING FORMS PART OF JACOBS
WHYFORD ENGINEERING LIMITED REPORT
NO. 7583 AND SHOULD BE READ IN
CONJUNCTION WITH THE REPORT

NOTES:

1. THIS DRAWING IS SOLELY INTENDED TO
ILLUSTRATE METHOD OF RE-ROUTING
SLURRY WASTES FROM BRINE TREATMENT
TANKS. DIMENSIONS AND ELEVATIONS ARE
APPROXIMATE OR BASED ON RECORD
DRAWINGS. READ IN CONJUNCTION WITH
REPORT SECTION 4.2 (OPTION 2).



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APP'D. NO.	DETAILS	DATE

CANADIAN SALT COMPANY LIMITED

**EFFLUENT
CONTROL**

PUGHISH, CAMBERLAND CO., NOVA SCOTIA

**SCHEMATIC
FOR NEW
SETTLING TANK**

Jacobs Whyford Engineering Limited
CONSULTING ENGINEERS AND ARCHITECTS

DATE	SCALE	DESIGN BY
92/31/01	1/8" = 1'-0"	P.J.SOD
APPROVED BY		DESIGNED BY
		A.S.RUSSELL



7583-8

5.0 ALTERNATIVE WASTE/EFFLUENT WASTE DISPOSAL AREAS

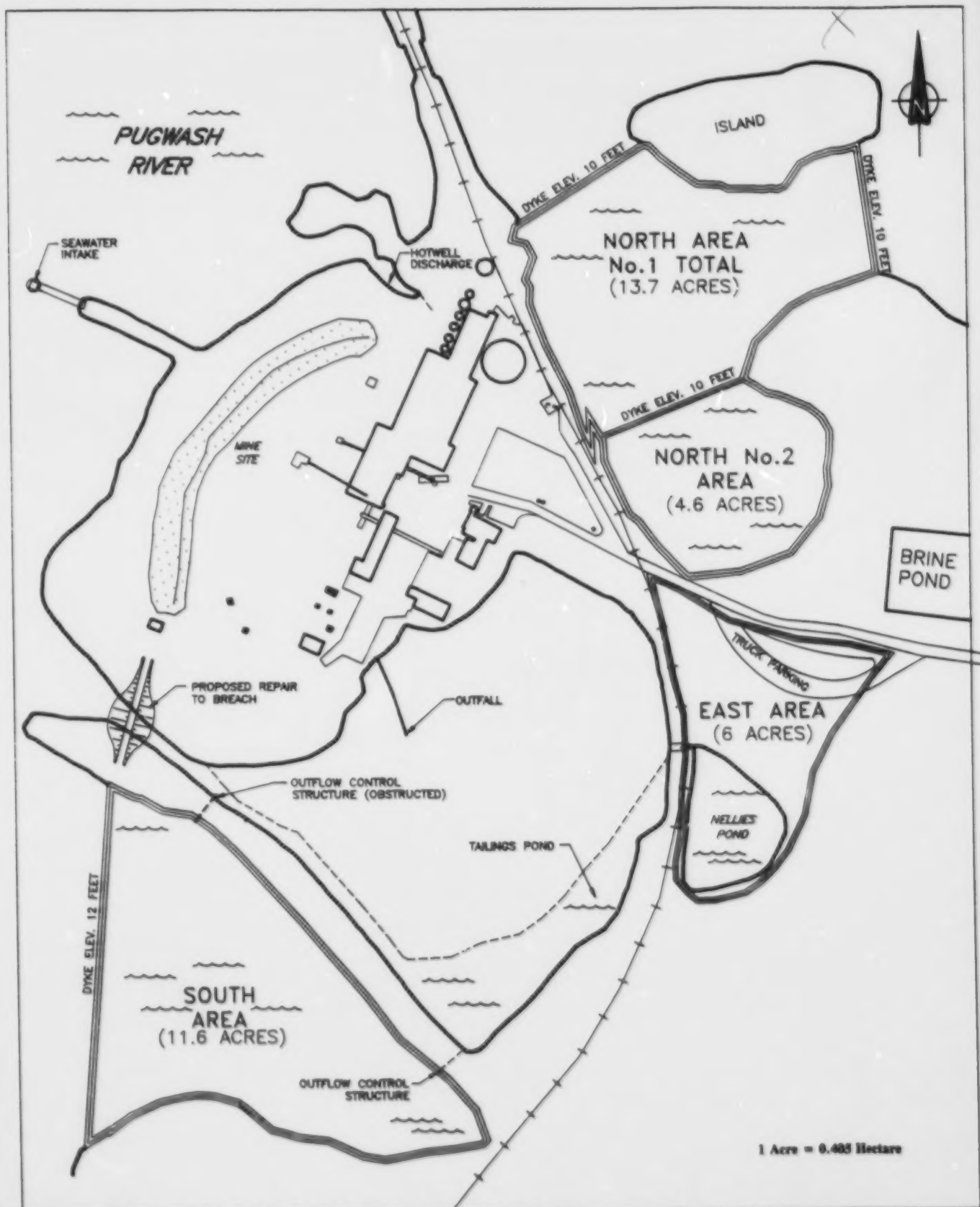
5.1 Alternative Tailings Sites

The tailings storage scheme for the Deep Cove area proposed in section 4.3.3 is limited to 7-8 years. Alternative sites were considered to supplement the Deep Cove disposal plans. Three possible candidate areas have been identified on Figure 5.1 as follows:

1. East Area : the area between the C.N.R tracks from the Nellies Pond location to along side the site access road.
2. South Area : the remainder of the inlet adjacent to and south of existing tailings area.
3. North Area : the cove between the brine pond and the mine site.

At this stage, consideration could be given to the use of the east area for solid tailings storage, particularly if the rail line is scheduled for abandonment. The coves to north and south are being considered for effluent retention only. If this was the case then additional volume in the existing tailings area would be liberated for disposal of additional solids. We have conducted a preliminary assessment of potential volumes in order to characterize each of the areas.

The East area is above the tidal reaches with the exception of Nellies Pond. In this location the solid tailings accumulations as in the present tailings area could be placed. The filling technique would involve placing the predominately gypsum-anhydrite solids in variable thickness to form the area to a gradual slope.



THE CANADIAN SALT COMPANY LIMITED
EFFLUENT CONTROL

PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIA
ALTERNATE TAILINGS SITES

Scale :
1" = 300'

Figure :
5.1

Date:
92/01/29

Dwn. By:
D.A.B.

App'd:



Jacques,
Whitford and
Associates Ltd.



The construction of any impoundment structure proposed within the tidal bounds would require further detailed assessment to obtain the proper approval and permitting from the regulatory agencies. Subsequent to the conceptual layouts illustrated in Figure 5.1, a detailed geotechnical investigation of the subsurface deposits would also be required. Geotechnical sampling, laboratory testing and engineering analysis would be essential to determine design parameters for new earthworks.

The selection of construction techniques would be important in this tidal environment. The use of cofferdams and/or special end dumping techniques of appropriately selected available materials would apply.

Some design concepts and estimated capacities for each area is presented below.

5.1.1 North Area

The North area can be divided into two sections depending upon requirements. A total section of 5.5 ha (13.7 acres) and a smaller of 1.9 ha (4.6 acres). It was assumed the seawater is 0.6 metres (2 feet) deep overall in the area at mean low tide or approximately at -1.5 metres (-5 feet) referenced to Canadian geodetic. The estimated containment of the area with an impoundment dyke placed to a crest height of 3 metres (10 feet) geodetic with a 0.6 metre (2 foot) freeboard allowance was computed to be:

Area #1 (total) 174,000 cubic metres or approximately 6.1×10^6 cu.ft

Area #2 48,500 cu.m or 1.7×10^6 cu.ft

The impoundment dyke total lengths of Area #1 is 200 m (650 ft) and would require 16,300 cu.m (575,250 cu.ft) of construction material using 3 to 1 dyke slopes. The Area #2 dyke length is 114m (375 ft) and would require 9400 cu.m (332,000 cu.ft) of construction material.

5.1.2 East Area

A location nearby at the present truck turning area adjacent the site access road and extending to a distance 244 m (800 feet) south past Nellies Pond may also be a candidate as a possible deposition site for the accumulated tailings. To assess the storage potential of this 2.5 ha (6 acre) area included the examination of local relief, drainage patterns and existing drainage structures. As well the existing C.N.R. and access road right-of-ways were observed. The relief of the area indicated a high of 10 m (35 feet) Canadian geodetic at east entrance of the truck parking area and a low in Nellies Pond to -1.5 metres (-5 feet) (Figure 5.1).

A preliminary evaluation was completed by contouring the existing area from available survey information and topographic maps. The depositional scheme called for filling the entire area including Nellies Pond, beginning from the east entrance of truck area at the present 10.7 metre (35 foot) elevation. The backfilling would be maintained generally at a 7% downward slope (present adjacent access road grade) to end to the west at the 4.6 metre (15 foot) contour along the right-of-way of C.N.R. tracks and past Nellies Pond to the south. The eastern side contact is higher ground.

The truck turning area would not necessarily be displaced but rather could be incorporated in its present location with the waste backfilling material if required. The drainage of the area to be maintained would require culverting or related catchment structures. Permitting by the regulatory agencies would be necessary.

The available volume of the site with the above scheme is 82,500 cu.m (2.9×10^6 cu.ft) and represents a storage life of 1.6 years based on a solid waste production of 90,000 tonnes (99,180 tons) annually. Storage could be increased by flattening the grade and maintaining a steepened 4 horizontal and 1 vertical slope at the contacts of the right-of-way restrictions. At the maximum, with a levelled top backfill to 35 feet and following the 4 to 1 criteria an extra 66,384 cu.m (2.3×10^6 cu.ft) is possible. This represents an increase of 1.3 years storage life.

Further storage space would again be possible upon the level 1.8 ha (4.5 acre) area pile top. Assuming another 4.6 m (15 foot) lift was undertaken to the 15 m (50 foot) elevation, with the 4 to 1 rule yet another 54,500 cu.m (1.9×10^6 cu.ft) is possible. This further represents a 1 year additional storage.

The total potential storage for the area would then be 4 years under these schemes.

The anticipated abandonment of the C.N.R. route in the future would open even greater storage potential. The area could be joined with the existing Deep Cove storage area. Although this storage has not been calculated this potential would be substantial.

5.1.3 South Area

The South area is an exposed tidal flat at low tide. It was assumed the 4.7 ha (11.6 acre) area is exposed at mean low tide or approximately at -0.9 metres (-3 feet) referenced to Canadian geodetic. The estimated containment area with an impoundment dyke aligned with the breach repair dyke and placed to a crest height of 3.6 metres (12 feet) geodetic with a 0.6 metre (2 foot) freeboard allowance was computed to be:

Total 138,000 cu.m or 4.8×10^6 cu.ft

The dyke length is 244 m (800 ft) and would require 20,000 cu.m (708,000 cu.ft) of construction material using 3 horizontal to 1 vertical dyke slopes.

Should this area be selected, provisions would as well have to be made to divert the flow of an inland stream discharging into this basin. This could be accomplished through culverting.

5.2 Underground Disposal of Salt Tailings

Limited capacity for the disposal of tailings within a surface containment facility at Pugwash may require CSCL to consider underground tailings disposal options as a part of an overall examination of tailings disposal options. A preliminary study has been conducted with the following main objectives to identify:

- The nature of the tailings and the surface preparation facilities
- Tailings Distribution System
- Underground areas for disposal
- Filling Practice
- Some examples of current practice.

Clearly, additional detailed technical work will be required to pursue underground storage concepts any further.

5.2.1 Tailings Characteristics

The tailings to be disposed underground consist primarily of anhydrite (CaSO_4) with minor amounts of gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) and undissolved salt (NaCl). Currently, this waste material is pumped to a surface disposal area. This section of the report addresses the potential for disposal of the mill tailings underground on the 630 level as an alternative to surface disposal.

5.2.2 Current Nature of Waste

The anhydrite waste is delivered to the disposal area as a slurry over a period of approximately 16 hours of each operating day. On an hourly basis, this slurry averages 583 tonnes brine @ 70% saturation and 21.7 tonnes of undissolved anhydrite and salt for a total of 605 tonnes/hr. The slurry has a density of 1.21 g/cc and is 3.7% solids by weight (1.43% solids by volume). On an annual basis, close to 90,000

tonnes of solid tailings are disposed of within the surface disposal site. This requires a storage volume of approximately 51,000 cu.metres (1,804,000 cu.ft) per year.

5.2.3 Underground Waste Disposal Option

The current investigation into the surface disposal system has indicated that within 8 to 10 years, the existing site will reach its ultimate capacity and alternative disposal areas will be required. One option is to dispose of the mill tailings underground in abandoned mined out areas. For the purposes of this study, the 630 level has been identified by Canadian Salt Company (CSCL) personnel as the preferred disposal area.

A number of potash mining operations in Canada, dispose of salt tailings underground as backfill. Typically, the salt tailings are transported underground in either a dry or slurry state and are disposed in mined out areas. The purposes of underground disposal at these potash operations is to provide ground support in active mining areas and/or satisfy government regulations which prohibit surface waste disposal.

Specific details on some of these operations and the methods they use for tailings transport and disposal are outlined in Section 5.2.13 of the report.

5.2.4 Tailings Preparation Prior to Underground Placement

Prior to placement underground, hydraulic tailings used in most backfilling operations are deslimed and thickened. Although the degree of thickening varies, the tailings slurry is generally thickened to between 40 and 70 percent solids by weight, frequently using hydrocyclones. These units, either operating as a single stage or a multi stage circuit, classify and dewater the fill to produce a high density, sands underflow and a low density, slimes overflow.

Other methods that can be used to thicken a tailings slurry include thickeners and rake or spiral classifiers. These methods are, however, rarely used today in this application because of high operating and maintenance costs, low through put and in the case of thickeners, excessive space requirements.

Hydrocyclones offer the following advantages over the alternative methods mentioned above.

- high capacity
- minimal space requirements
- low capital, operating and maintenance costs
- reasonable effectiveness
- flexibility

Preparation of the salt tailings for underground disposal can also take the form of dewatering to a moisture content of between 5 and 10 percent and transporting the tailings underground in a "dry" state. Drop pipes are normally used to transport the tailings material underground from surface. Details on the drop pipe method for transport of dry tailings and how it is used as a method of tailings preparation and transport as undertaken by the Potash Company of America, in Sussex, New Brunswick, are outlined in Section 5.2.14.

The tailings preparation option which is considered most feasible for the Pugwash operation is to transport the tailings underground as a slurry. This option was selected based on the current state of the anhydrite tailings currently produced at the mine site. Following placement underground the decanted brine, will be pumped back to surface for disposal.

Two alternatives are available for surface preparation of the Pugwash mill tailings prior to underground disposal. Option No. 1 is to transport the tailings underground in their current form, with no surface preparation. Option No. 2 involves thickening

the tailings prior to underground transport. Each option has a number of cost and operational advantages and disadvantages which must be considered.

5.2.4.1 Option No. 1 - Unthickened Tailings Slurry

By transporting the tailings underground in their current state, no surface facilities are required to thicken the tailings slurry. The decant brine can be left to clarify underground and can then be pumped to surface for marine disposal. Offsetting the advantages mentioned above are the following disadvantages of sending the unthickened tailings slurry underground for disposal.

- Larger diameter pipes are required to transport both the slurry underground and the decant brine back to surface. This results in increased capital and maintenance costs. For this application, it is estimated that an 8" (200 mm) diameter pipe line would be required for transport of the slurry underground, and a 10" (250 mm) diameter line required as a brine return line. The size of the brine return line may vary depending upon the type of pipe used and the location of the pumps. The 250 mm (10 inch) pipe size was chosen to minimize both the friction losses and flow velocity, to keep the pump horsepower requirements low.
- Pumping facilities underground must be sized to accommodate the large quantities of brine which must be returned to surface. Using a 250 mm (10 inch) brine return line, to pump an estimated 38 million l/s (600 million US gallons), of decant brine to surface annually would require approximately 970 kilowatts (1300 HP) of pumping capacity.
- Brine handling facilities underground must be provided to allow adequate clarification time. On an annual basis, approximately 38 million l/s (600 million US gallons) of decant brine would require clarification prior to being pumped to surface.

A schematic drawing of the unthickened tailings transport system is shown on Figure 5.2.

5.2.4.2 Option No. 2 - Thickened Tailings Slurry

Thickening of the mill tailings on surface to 60% solids by weight, would significantly reduce the quantity of brine which must be transported underground and subsequently pumped back to surface for disposal. The reduced quantity of slurry transported underground would permit the use of a 100 mm (4 inch) diameter pipe line for slurry transport. The requirement to pump smaller quantities of brine back to surface will also result in less extensive brine handling facilities underground and smaller pumping requirements. Preliminary calculations show that a 60 kilowatt (80 HP) pump would be required to pump the decant brine back to surface at a rate of 10.7 l/s (170 US gallons) per minute.

The 60% solids by weight value is based on typical Canadian filling practice (E.G. Thomas et al) and was taken as an initial estimate and a starting point for calculation. It may prove to be too high a solids content for efficient transport. The relatively high solid content could also produce excessive wear in the pipe system. Investigations into the flow characteristics of various slurry densities would be required to optimize the slurry density with efficient and economical flow characteristics.

Thickening of the tailings slurry on surface does, however, require the installation of a hydrocyclone(s), and a facility to deslime and clarify the hydrocyclone overflow. A thickener or surface settling pond could be used to deslime the hydrocyclone overflow and produce a clarified overflow suitable for marine disposal. Whichever choice is made, the system must be designed to handle in the order of 570 tonnes/hour (628 tons/hr) of slurry from the hydrocyclone. If a thickener was used, the underflow

could be directed back to the thickened tailings stream from the hydrocyclone and disposed of underground.

A schematic drawing of the thickened tailing disposal transport option is shown on Figure 5.3.

5.2.5 Surface Tailings Slurry Storage

Most tailings fill operations include some form of fill storage between the preparation hydrocyclones and the underground disposal area. Storage facilities are generally required because of the mismatch between tailings supply from the mill and the demand or the ability to accept the tailings in the mine due to production scheduling. Because the proposed underground disposal of tailings at Pugwash does not form part of the mining system, the tailings can be transported and disposed of on a schedule more consistent with the mill.

Should it be necessary to store the tailings prior to underground disposal, there are two acceptable methods. The tailings may be retained in an agitator tank where the solids are kept in suspension, or allowed to settle in a surface disposal area. Allowing the tailings to settle out in a disposal area, such that they require repulping is not recommended. The repulping operation generally results in pulp densities which are low and difficult to control. It may also still be necessary to thicken and deslime the repulped tailings prior to underground disposal.

Tailings storage of any form involves both a capital and operating expense and since there is no requirement to schedule the tailings disposal with mining, surface storage should be avoided if possible.

To avoid the requirement for surface storage during periods when the slurry transport is out of operation for maintenance, a second slurry line should be considered. This

back-up line would permit uninterrupted tailings transport and disposal during the period one of the pipe lines is down for maintenance or repair.

5.2.6 Tailings Distribution

A tailings slurry could be transported underground using a pipe line within an existing shaft. Technology to design and operate these methods of materials transport is well documented and the hydraulic fill method of backfilling is extensively used in mining operations worldwide. The hydraulic fill is distributed as an aqueous slurry, through a system of pipe lines or boreholes, incorporating both horizontal and vertical components. Transport can be entirely under the action of gravity, or with the aid of pumps. A rule of thumb, is that when the ratio of the horizontal transport distance to the vertical distance approaches four to one, the need for pumping must be considered. In the Pugwash application, this would mean that it should be possible to transport a tailings slurry for a distance of 750 m (2500 ft) on the 630 level by gravity. For the purposes of this report, a maximum horizontal distance of 600 m (2000 ft) has been assumed and pumping has not been considered underground..

Basic design principles which should be considered for a slurry system include the following.

- The solids concentration of the slurry should be as high as possible in order to minimize the volume of water transported with the fill and ultimately requiring pumping back to surface.
- The flow rate of the material through the pipe lines or boreholes should be as slow as possible to minimize wear, but must be high enough to hold the coarse fractions in suspension during transport. Experimentation is required to determine the optimum rate, however, empirical formulas are available to calculate flow rates based on the material properties and the pipe diameter and friction characteristics.

- The overall flow velocity through the transport lines should be held constant. This will minimize the tendency for surging, vibration, plugging and non-uniform wear of the delivery lines. This can be accomplished by properly sizing the transport pipes to ensure full-flow conditions and maintaining a constant slurry density.
- Normally slimes should be removed from the tailings slurry to facilitate and promote more rapid decant and improved pecculation of the transport water. Since the anhydrite tailings at the mine site settle quickly and the anhydrite consolidates to a hard, competent state, this requirement may not be of critical importance in this application.

The following outlines the tailings transport, distribution and transport system proposed for the Pugwash mine. The system as outlined is based on a conceptual study only, and would require a detailed engineering evaluation prior to implementation.

5.2.6.1 Proposed Tailings Distribution System

Surface to underground transport of the tailings slurry, would be via a pipe line in one of the two shafts. Unless surface storage capacity is available, two slurry pipe lines are recommended. This will permit uninterrupted transport of the tailings during periods when one line is out of service for repair and maintenance.

For transport of a thickened tailings in the order of 60% solids by weight, a 100mm (4 inch) diameter pipe should provide adequate capacity at an acceptable flow rate in the order of 3 to 5 m/s under gravity induced full flow conditions. At 60% solids, the calculated mass flow rate would average approximately 35 tonnes/hr depending upon the degree of slimes removal during the hydrocycloning operation. Of this total 35 tonnes/h approximately 15 tonnes/h would consist of brine and 20 tonnes/h of undissolved anhydrite and salt.

If an unthickened tailings is transported underground at a 3.7% solids by weight concentration, a 200 mm (8 inch) diameter pipe line is suggested. Under gravity induced, full flow conditions, the flow velocity has been calculated at between 6 and 7 m/s. At 3.7% solids, the mass flow rate would average 605 tonnes/h, which would consist of 477 tonnes/h brine, 106 tonnes/h dissolved salt and 22 tonnes/h of undissolved anhydrite and salt.

For preliminary design and costing purposes for both transport options, we have selected a schedule 80, hardened steel pipe for the shaft portion of the system. Maximum calculated line pressures at the 630 level of the vertical pipe for both the thickened and unthickened option are 3450 and 2400 kPa (500 and 350 psi) respectively.

Because lower line pressures will be developed in the horizontal section of the transport pipe line, a high density polyethylene or PVC pipe is recommended. These types of pipe are easy to install, maintain and are generally less costly than a steel pipe of an equivalent diameter. For costing purposes, Schedule 160 and Schedule 250 Yelomine™ PVC pipe has been used.

By selecting disposal sites within a 600 m (2000 ft) radius of the shaft area, pumps should not be required to transport the slurry area underground. As experience is gained with the system, it may be possible to adjust operating parameters to extend this disposal area radius before pumps are required. A pump will, however, be required to transport the tailings slurry from the mill to the Shaft collar on surface.

5.2.7 Choice of Shaft

To assess in which of the two shafts to install the slurry line, consideration was given on the following. The existing conditions of the two shafts determined from discussions with CSCL personnel and review of mine drawings, were also important factors in the recommendation.

- Access should be available along the full extent of the shaft from surface to the 630 level. This is important to facilitate the installation, inspection and maintenance of the slurry line.
- The slurry pipe line and the support brackets and hardware, must not hinder the operation of the shaft nor protrude in any way into the conveyance travelways. It should also not impact on the ventilation by significantly reducing the cross-sectional area of the shaft or increasing the resistance of the airway.
- Shaft timbers or appropriate support structures should be available at suitable intervals to which the slurry line can be attached.
- In the event of a leak or ruptured pipe, hazards to both individuals and conveyances using the shaft must be minimal.
- Access to the shaft bottom should be available to facilitate the removal of any material resulting from a leak or broken pipe.

Based on the above criteria and review of the available information for both shafts at Pugwash, advantages of each are presented.

No. 2 Shaft offered the following advantages.

A suitable location for the slurry pipe line is within the manway section of No. 2 Shaft. The shaft timber and manway may provide some impediments to installation and maintenance.

- The pipe line will be accessible for both inspection and maintenance over its full length.

- The pipe line will not interfere with the shaft operation and can be supported in the shaft along its full length by the shaft timber.
- The pipe line will have a minimum impact of the shaft cross-sectional area resulting in insignificant affects on the mine ventilation.

No. 1 shaft offers the following advantages:

- The present 250 mm (10 in) pipeline to Deep Cove was routed so as to be immediately adjacent to #1 Shaft at the elbow so that minimal changes will be required to divert the tailings underground.
- A 100 mm (4 in) standard steel pipeline was installed in #1 Shaft during repairs and is installed in what was called the North skip compartment. It is cast in the concrete through the repaired section and, like most backfill lines, is mounted on brackets on the dividers. Individual pipe lengths can readily be replaced from the conveyance in the sections above and below the repaired section.
- The existing pipe should have a life of at least three years. Its location is such that it does not interfere with ventilation in #1 Shaft.

We recommend that the final selection of shaft be reviewed and an operational decision at the time of installation.

5.2.8 Potential Areas For Tailings Disposal

A preliminary review was made of the 630 level and three potential disposal areas were identified. Each of these areas is within the 600 m radius of the shaft, and are not currently used as ventilation routes, storage areas or access roads to the shafts or the storage areas on the 630 level. As shown on Figure 5.4, Area No. 1 is located to



the north of No. 2 Shaft, Area No. 2 is located to the east of the shaft, while Area No. 3 is positioned south of the shaft area.

Assuming the tailings can be disposed of to a height of 12 m (40 ft), and a total storage volume of 51,100 m³ (1,804,000 ft³) is required on an annual basis, the storage capacity and life of each area is detailed below.

Area No. 1

Storage Capacity: 194,100 m³ Life: 3.8 years

Area No. 2

Storage Capacity: 153,300 m³ Life: 3.0 years

Area No. 3

Storage Capacity: 157,400 m³ Life: 3.1 years

TOTAL **504,800 m³** **Life: 9.9 Years**

As shown above, the total estimated life of the three potential tailings disposal areas, at current rates of production, is 9.9 years.

The suitability of these areas will have to be confirmed with an underground inspection. Elevations would also be required to more accurately estimate storage capacity. Slumping arrangements would also have to be identified to minimize localized pumping and promote natural drainage to sumps and water collection areas.

Additional cost elements which must be considered in establishing underground disposal of the salt tailings into these areas would include the following.

- Costs to establish electrical service, ventilation and telephone communications.

- Costs of ground control requirements to provide safe access and working conditions in both the disposal areas and headings leading to these areas.
- Costs to establish pumping facilities to pump the decant brine back to surface.
- Costs to construct bulkheads and control structures to direct and control the placement of the tailings slurry.

5.2.9 Bulkheads and Flow Control Structures

Bulkheads will be required to direct and control the flow of the tailings slurry to permit

controlled filling of the selected disposal sites. Typically, bulkheads used for hydraulic fill applications are constructed of wooden planks attached horizontally to vertical posts. Depending upon the height of the opening, the vertical posts are anchored to both the floor and back of the underground opening. Gaps are generally left between the horizontal planks to permit some of the decant water to drain through the bulkhead. Floor drains or decant towers connected to floor drains, are also used to drain the majority of the decant and percolating water. To help filter out fines carried by the decant water, burlap or a fabric filter is often attached to the downstream side of the bulkhead, between the planks and the vertical posts. Its effectiveness in some applications is questionable, however, as very fine material tends to plug the burlap or fabric material and impede the flow of water.

Because the openings which exist in the three proposed disposal areas could exceed 10 m (30ft) in width and may be over 15 m (50 ft) in height, fill fences of the type used in large cut and fill stopes may be more suitable than bulkheads. Using this method, the vertical height of any one filling operation will have to be limited to a height of between 2 and 3 m (6 and 10 ft) across the 9 metre (30 foot) wide opening.

Engineering studies will be required to establish the hydrostatic forces which can be expected to develop behind the fill fences or bulkheads. These forces will relate to the percent of water contained in the tailings slurry, the percolation and decant rate and the method of tailings placement.

It will also be important to determine the settling time of the thickened tailings slurry. This is necessary to permit the scheduling of subsequent filling over previously filled areas, in order to develop the maximum disposal height possible.

5.2.10 Decant Brine Handling

The quantities of decant brine which must be handled and ultimately pumped back to surface will depend on the percent solids the tailings are thickened to. If unthickened tailings are transported underground for disposal, approximately 2.5 million tonnes (2.7 million tons) of decant brine must be pumped back to surface on an annual basis. If a 60% solids by weight tailings slurry is transported underground, this quantity decreases to about 53,000 tonnes (58,400 tons) per year. Pumping facilities will be required at the disposal site, and possibly also at the base of No. 2 Shaft, depending upon the quantities of water which must be handled.

To facilitate pumping in a cost effective and practical manner, sump and water control facilities will be required at the disposal site to allow continuous pumping as requirements dictate. By distributing the pumping time over a longer period and not just during the time filling is being carried out, both pipe line diameter and pump horsepower requirements can be optimized.

CSCL personnel advise that there is a 100 mm (4 in) pumpline up #2 Shaft from the 830 level that discharges directly into Deep Cove. This is used on an intermittent basis to pump water from the 830 Level Sump to surface. It can be used to pump decant water from the 630 Level.

CSCCL purchased a multi-stage submersible pump at the time of the shaft repair to pump water from the sump at #1 Shaft to surface while repairs were in progress. This handled an inflow rate of 5.7 l/s (90 USGPM) and would be ideal for pumping the decant water.

5.2.11 Filling Operation

To ensure safe and trouble free operation during filling operation, underground control is necessary. Through a telephone connection, the underground backfill personnel should be in direct contact with the personnel on surface who control the surface feed. Prior to commencing a backfilling operation the lines should be flushed with water. This operation ensures that all the lines are open and the fill will be directed to the correct location. This is very important if there are more than one possible routes for the fill to travel. Following confirmation that the lines are open and correctly configured, the surface backfill operator can initiate the flow of fill into the system.

Once sufficient fill has been received, taking into account the fill remaining in the line following shut-off, the surface fill operator is contacted to shut off the fill line. Considering the not continuous production of tailings in this application, it may actually happen that the surface tailings supply is exhausted prior to the underground disposal site being filled. Regardless, after filling is complete, water is again run through the lines to flush out any remnant fill and ensure the lines are open for the next application. This flush water should be directed into a sump, rather than into the disposal area.

Distribution of the fill to various areas should be carried out by physically connecting and disconnecting the pipe lines from the main feeder. Valves tend to corrode, wear excessively and promote line blockages.

5.2.12 Environmental Issues

Placement of hydraulic fill in an underground salt mine will result in increased humidity levels. The extent of the areas affected by the increased humidity will be a function of the ventilation, temperature and amount of water associated with the tailings. This increase in humidity can lead to increased corrosion of equipment, problems with electrical contacts and switches and can also result in minor ground control problems.

There may be a possibility of water channelling to the 730 level, if filling is carried out in areas of the 630 level which overlay openings on the 730 level. Of the three potential storage areas, only Area No. 3 overlays openings on the 730 level. The location of diamond drill holes and the geological conditions should be determined prior to filling in this area. A similar investigation would be warranted in any other areas selected for filling.

Establishment of a slurry and brine pipe within an active production or service shaft or raise, may require the approval of the Department of Labour, Mines Inspection Branch. Concerns the Department may have over the impact of a spill resulting from a broken pipe and the inspection requirements they would expect should be determined during the planning stage prior to detailed engineering.

Possible future plans to mine between the 850 and the 630 level must be kept in mind when disposal areas on the 630 level are selected. Vertical stopes of this nature might, however, offer suitable receptacles for salt tailings disposal, and development and stoping plans should reflect this possibility.

5.2.13 Canadian Mines Using Slurry Pipe Line Tailings Disposal

One New Brunswick and two Western Canadian potash producers use a slurry method to transport waste salt tailings underground for backfilling operations.

Potacan, located near Sussex, New Brunswick transports a tailings slurry underground using a shaft pipe line. The two western Canadian potash producers utilize drill holes from surface to the underground workings to transport a tailings slurry for backfilling operations. IMC Canada use salt tailings to backfill unstable areas near a major water inflow at the K-2 potash mine in Esterhazy, Saskatchewan. Kalium Canada Ltd., located near Moose Jaw, Saskatchewan, use a salt tailings backfill, delivered in the form of a slurry, to stabilize mined out areas of their underground solution potash operation.

5.2.13.1 Potacan, Sussex, N.B.

The salt tailings slurry used by Potacan for their underground backfilling application is pumped from the mill at approximately 15% solids by weight. From the mill, the tailings are transported down the No. 2 Production shaft in a 200 mm (8 in) diameter steel pipe line. This is a high strength steel line, which increases in strength with depth. From the shaft, the tailings are transported through to the stopes to be filled using polyethylene pipe. The maximum pipe diameter of the polyethylene pipes are 200 mm (8 in) and all joints are thermally connected. Polyethylene pipe was selected for underground use because it is bendable, inexpensive, reliable and easily installed.

Prior to fill being directed into the stopes which are to be backfilled, bulkheads are constructed across the entries and access drifts leading into the stope. The bulkheads are wood construction and rigidly affixed to the perimeter of the access opening using bullhorns and cable supports. During construction, the bulkheads are lined with a filter fabric to help filter out the slimes and salt fines as the water seeps through when the stopes are filled.

Filling within individual stopes is maintained for between 12 and 15 hours, then is stopped to permit the brine to decant. During the decant period filling operations are switched to another stope. After the decant period, filling recommences. Decant brine from the filling operations is allowed to naturally drain, or in some situations

is pumped to a sump located near the backfilling area. From the sump, the brine is pumped to surface.

The switch from a drop pipe, dry tailings backfill system, to a slurry backfill method at the Potacan operation was made approximately two years ago (1989). The primary reasons for the change in methods was to reduce the exposure of mine personnel in the old, mined out stopes and to reduce backfilling costs. Exposure by the underground personnel is now basically limited to the entries leading into the stopes where the bulkheads are constructed.

Following a number of initial start-up problems, the slurry system has operated satisfactorily and has been cost effective (G. Bagnel). Since abandoned, mined out areas are being filled the decant water causes no operational problems. Humidity levels increase in the areas where filling is taking place. The walls and backs of the underground excavations become wet and minor surficial ground control problems result. This is caused primarily because of clay seams which swell due to the increased humidity. The temperature also increases because of the exothermic reaction which accompanies the crystallization of the salt tailings.

5.2.13.2 IMC Canada K-2 Shaft, Esterhazy, Sask.

Salt backfill is utilized at IMC Canada K-2 Shaft, as a ground support measure in washout and collapsed areas near a major water inflow. The inflow water, although saturated in NaCl is low in K and Mg. This has resulted in significant dissolution of potash and carnalite pillars, resulting in unstable ground conditions. To stabilize this area it was decided to backfill washout and collapsed areas with salt tailings.

The washout area is located approximately 1.6 km (1 mile) south of the K-2 Shaft. It was therefore decided to utilize a drill hole from surface positioned near the inflow area, to transport the salt tailings to the potash elevation. Because of cost considerations, the requirement to tight fill the areas, bad ground conditions in the

infill areas and the ability to handle the decant brine using existing pumping facilities, a slurry transport and placement method was chosen.

A vertical hole was drilled from surface into a pillar located approximately 30 m from an access drift near the inflow area. A 139.7 mm, 34.23 kg/m., N-80 casing was installed as an injection line within the borehole. At the 980 m (3200 ft) elevation (potash mining horizon), the vertical line was connected to a horizontal, 150 mm (6 inch) diameter, 160 schedule steel line using a 90 degree, ceramic lined elbow. High strength pipe was initially utilized for the horizontal because of a concern that a blockage in the line would result in excessive pressures. Once in operation, however, it was discovered that the outlet pressures were in the order of 0 to 170 kPa (0 to 25 psi) and the pressure at the base of the vertical borehole varied between 2050 and 4100 kPa (300 and 600 psi). With this knowledge, the high strength horizontal pipe was replaced with Sclair™ pipe. The Sclair™ pipe offered an attractive replacement because of its cost differential and ease of handling and placement. As a precautionary measure, pressure values were installed along the Sclair™ pipe sections to monitor pressure build-up. If such occurred, the feed could be turned off at surface and the line can be dumped upstream of the blockage to prevent a rupture of the pipe line.

Bulkheads are established in the areas to be filled. Initially, bulkheads were constructed with 150 mm x 150mm (6" x 6") rough timbers, positioned vertically between the floor and back, and supported to the back with rockbolts and cable. Attached horizontally to these posts, with a 20 mm (3/4") gap between them, were 75 x 200 mm (3" x 8") rough timbers. On the downstream side, burlap was attached between the horizontal planks and the vertical posts. The purpose of burlap and the gaps was to allow the brine to bleed out through the bulkhead as filling progressed. During filling operations, this proved not to be the case, as the brine did not decant fast enough and the burlap became plugged with salt. A head then develop on the brine and it would drain out at an increasing velocity, resulting in erosion of the recently placed tailings. To correct this, a 1 m notch was left in the middle of the



bulkhead to permit the decanted brine to drain through thus preventing the development of any hydrostatic head. As filling advanced, and salt began to accompany the decant brine, a plank was dropped into the notch. This process would, continue until filling reached the top of the bulkhead. This process was adapted as standard operating procedure, although the gaps were still left between the planks on the bulkhead to reduce the total amount of material used and because the gaps did permit a minor amount of brine to decant through the bulkhead.

Control of the backfilling operation is from underground. Through a telephone connection, the underground backfill personnel are in direct contact with the personnel on surface who control the surface feed.

Decant water is directed to sumps which are located near the areas being backfilled. From the sumps, the brine is pumped to surface. A series of sand bag dykes are used to help settle out the salt contained in the brine, however, in most cases, the sump pumps become salted in and the sumps must be cleaned out with a scooptram. Since the backfilling operations are being carried out in the area of the major water inflow, the decant tailings water can be pumped to surface utilizing the existing pumping facilities.

The initial slurry density was typically 20% (by weight), however, modifications to the surface pumping system allowed the density to be increased to 30%. Prior to the transport of tailings slurry, a water was flushed through the lines to ensure that there were no blockages. Once it was determined that all lines were open, the surface tailings slurry lines were opened and filling began. At the termination of filling, a brine flush was again put through the lines.

Since its inception in 1987 and a few initial start-up problems, the slurry backfill operation at IMC's K-2 Shaft has proven to be economical and has performed without any major problems.

5.2.13.3 Kalium Canada Ltd., Moose Jaw, Sask.

Kalium Canada Ltd. produces potash using a solution mining method in southern Saskatchewan, near Moose Jaw. To stabilize the old solution caverns developed during mining, a salt tailings slurry is disposed of underground into the openings using abandoned production wells.

5.2.13.4 Other Backfilling Operations

No other Western Canadian potash producers use backfilling as part of their normal production operations. All mill waste is disposed of on surface disposal areas. Some limited backfilling was carried out at Norandas Central Canada Potash operation in Colonsay, Saskatchewan, however, salt used for this application was mined from underground.

5.2.14 Dry Tailings Disposal Using a Drop Pipe

Although not directly applicable to the this application, details on the use of a drop pipe for the transport of a relatively dry salt tailings is included for completeness.

5.2.14.1 Dry tailings Drop Pipe Application

A drop pipe is in use at one New Brunswick potash mines and a number of German and European salt and potash producers as a means of transporting tailings underground for disposal and backfill applications. In Western Canada, the Potash Corporation of Saskatchewan carried out a detailed engineering study and field investigation to determine the feasibility of drop pipe technology to deliver salt tailings waste underground. The system, however, was never installed (M. Woolley).

The basic concept of the drop pipe is to allow the waste material to free fall within the confining area of a pipe line. Although detailed engineering data on the existing systems was not obtained a number of general design guidelines can be listed.

1. The diameter of the drop pipe must be suitable to permit flow rates sufficient to meet present and future anticipated production requirements. Determination of this diameter to optimize cost and production requirements can be carried out using field tests or mathematical modelling. If a backup surface disposal or storage area is not available, a second drop pipe should be installed. This will allow for uninterrupted tailings disposal when one of the pipe lines is out of service for maintenance or repairs.
2. A surge bin of some nature should be positioned vertically over the inlet of the pipe to permit a constant flow of tailings into the drop pipe. Feed to the surge bin can be supplied from a larger hopper or storage pile using a conveyor system, vibrating feeder or auger.
3. An air inlet with a valve cutoff control located directly below the surge bin at the drop pipe inlet may be required. Depending upon the nature of the inlet feed hopper and feed rates, air inflow is required to equalize pressure along the length of the pipe. This source of air is required due to the fact that a significant amount of air is dragged downwards by the free falling tailings particles. Once the drop pipe is operating at a steady state flow over its full length, the air line valve can be closed since the tailings solids virtually fill the pipe volume and very little air is entrapped. Failure to follow this procedure can result in blockages in the drop pipe line during initial start-up.
4. The moisture content of the tailings should be between 5 and 10 percent by weight. Within this range the material falls freely, does not tend to adhere together or build up on the pipe walls and does not generate significant decant water.

5. The discharge end of the drop pipe must not be constricted and allow free discharge of the material into a receiving hopper. Sharp bends at the bottom of the pipe line must be avoided to prevent blockages and excessive wear of the pipe at the bend. A long, gentle curve is permissible. Horizontal sections of pipe at the discharge end must be avoided, as they tend to develop a bed of tailings which will restrict the available transport area and result in blockages. To eliminate this, the underground receiving hopper should be as close to the vertical portion of the drop pipe as possible.
6. The drop pipe should be a lined or hardened steel, abrasion resistant pipe. This is most important over the lower portion of the line and in any location where the pipe bends and a direct contact surface is developed. Wash water inlets established at regular intervals along the pipe length can also be installed in the event of a blockage within the pipe. The pipe should also be installed in manageable lengths so individual sections can be removed as required.

5.2.14.2 Drop Pipe Design Criteria

Design of a vertical drop pipe system must take into account the wear mechanisms on the pipe, the column strength of the pipe, dynamic pipe loading considerations and the pipe support method. Wear mechanisms to consider in the pipe selection include corrosion, abrasion and to a lesser extent fatigue and adhesion wear resulting from the transport of the waste. Evaluation of the expected wear will depend primarily on the physical properties of the waste and the pipe material. Key factors in the selection of the drop pipe are:

- Corrosion Wear
- Abrasion Wear



- Adhesion Wear
- Column Strength
- Dynamic Loading
- Pipe Supports

5.2.14.3 Necessary Surface Facilities

The tailings from the Pugwash mill are presently disposed of in a state which is not suitable for transport within a drop pipe. Processes on surface will therefore be required to dewater the tailings slurry to a suitable moisture content. This would require the installation of a dewatering system which may include centrifuges, thickeners, filters and/or screens to dewater the tailings slurry prior to transport underground.

5.2.14.4 Current Drop Pipe Practice

The Potash Company of America use a drop pipe to transport salt tailings underground at their potash mine located near Sussex, New Brunswick.

The reason for underground disposal at PCA is to provide support as backfill in their underground mining operation and to comply with Provincial Legislation.

Prior to transport underground, the tailings are centrifuged in the mill to a moisture content between 6 to 8 percent by weight. The dewatered tailings are then transported from the mill to the service shaft on a conveyor. In the service shaft headframe, the tailings are discharged from the conveyor into a cone shaped chute positioned directly over two, 200 mm (8 inch) diameter drop pipes. Depending upon

which drop pipe is in use, the tailings are then transported underground in the service shaft to a receiving hopper which is located directly below the drop pipes.

From the underground receiving hopper, the tailings are transported from the shaft area to the mine workings on a dedicated conveyor system. Once the tailings reach the designated disposal area, they are carried into the stope using a conveyor and placed with a scooptram.

Because the underground tailings disposal system at PCA is required to handle all the mill tailings, two drop pipes were installed. This permits continual operations in the event of a blockage or maintenance requirements on one of the lines. The tailings can also be diverted into a storage area on surface adjacent should it be necessary to suspend underground transport. This storage area has capacity for one days mill production.

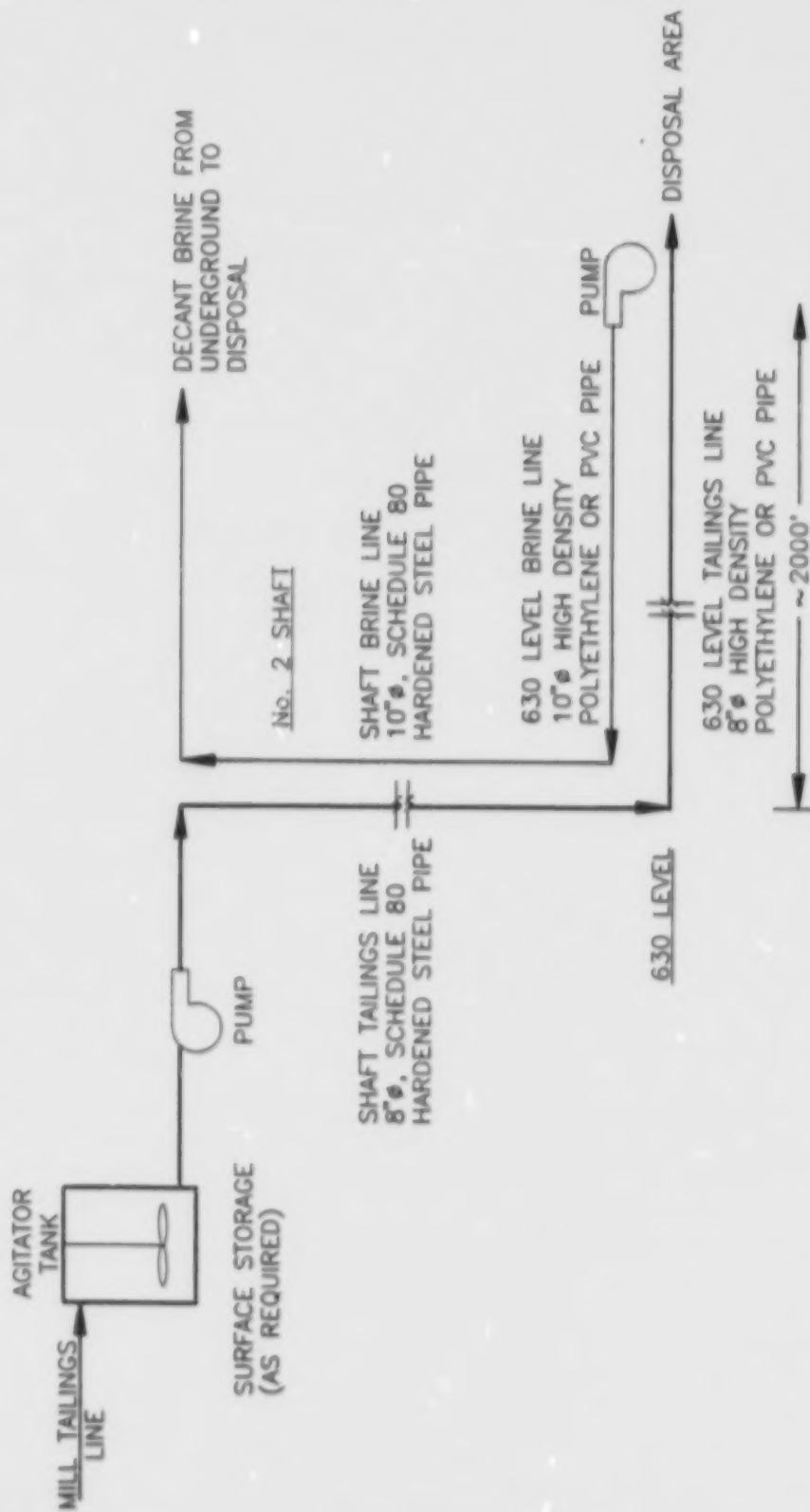
The drop pipes are manufactured from a hardened, heat treated steel and installed in sections. During routine shaft inspection, the pipes are checked for wear, which is usually evident in the form of holes. As required, the worn sections are removed and replaced. Blockages in the drop pipes have not been a problem, other than during the initial start-up period. The system at PCA does not utilize an air inlet.

The tailings discharge into the underground receiving hopper initially resulted in significant wear on the receiving surface. This problem has been solved by using a granite block to replace metal wear plates.

The drop pipe system at PCA was the first installation of this nature in Canada. Other than a few initial start-up problems, the system has been very successful.

The tailings size gradation corresponds to a poorly graded, fine sand, with a coefficient of uniformity (D_{60}/D_{10}) of 4.8. A screen analysis of the material indicated that approximately 90% of the particles are between 2 mm and 0.125 mm in size.

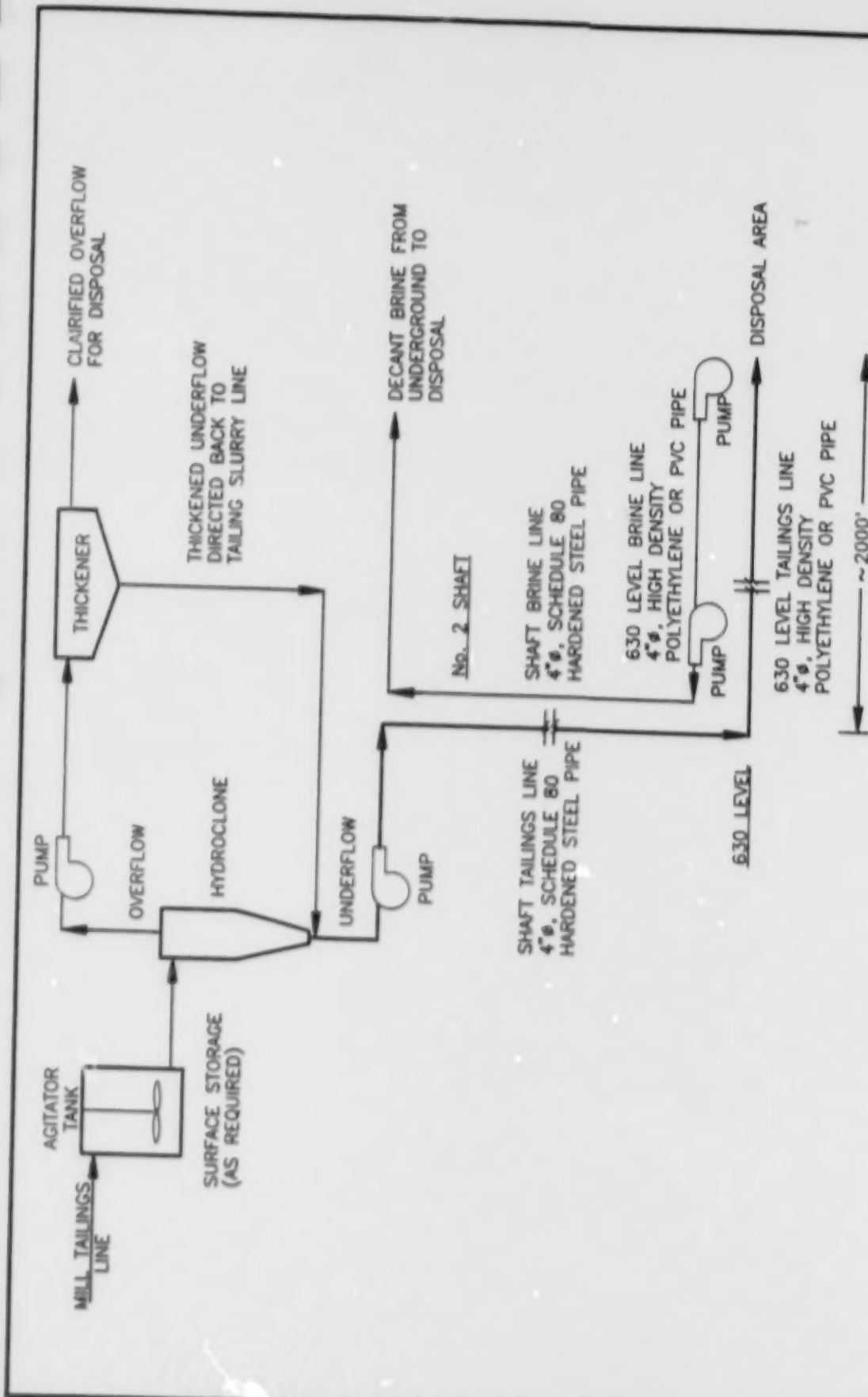
The moisture content at the stope averages between 6 and 8% water by weight (R. Beddoes et al, 1989).



CANADIAN SALT COMPANY
UNDERGROUND TAILINGS DISPOSAL
UNTHICKENED TAILINGS - OPTION No. 1

NOT TO SCALE

FIGURE 5.2

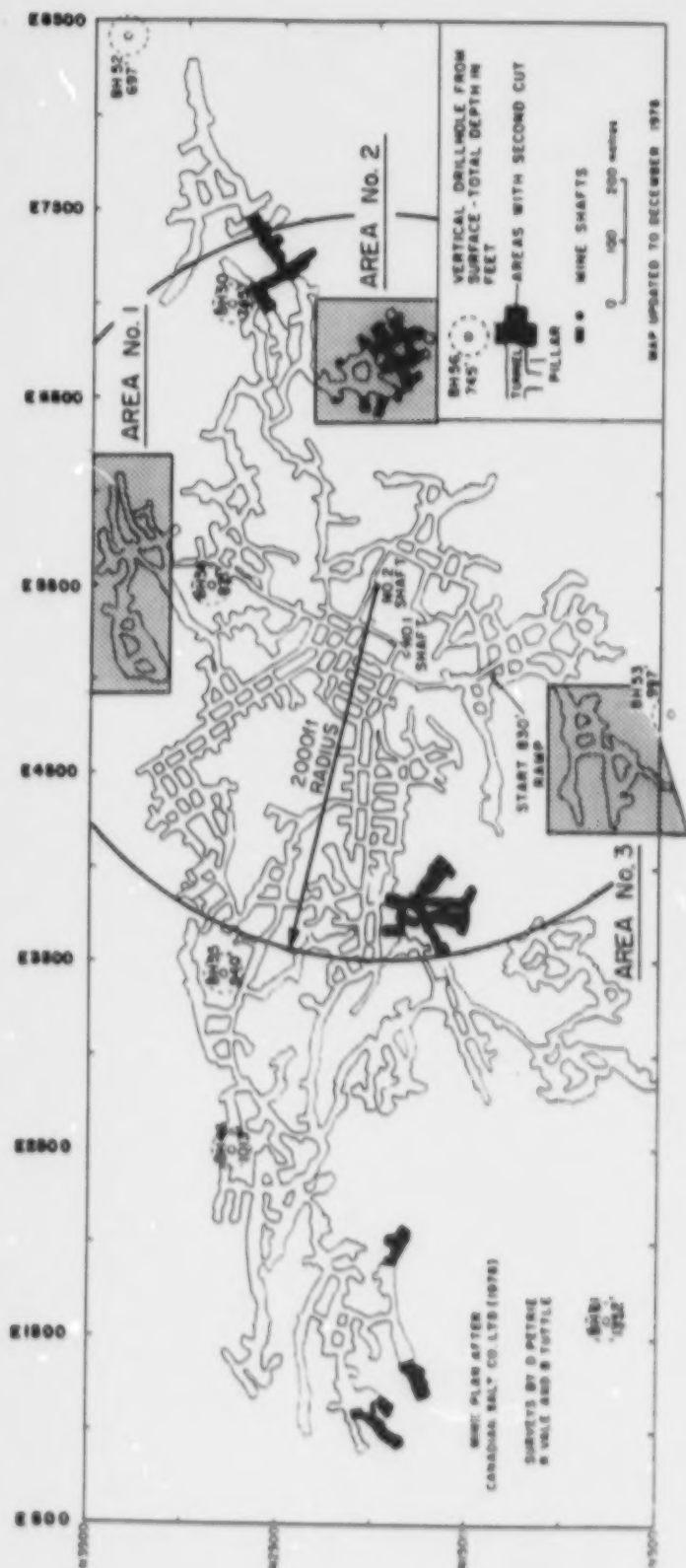


1 inch = 25 mm
1 foot = 0.3048 metres



CANADIAN SALT COMPANY
UNDERGROUND TAILINGS DISPOSAL
THICKENED TAILINGS - OPTION No. 2

NOT TO SCALE



AREA	STORAGE CAPACITY	LIFE	DISTANCE FROM No.2 SHAFT
No.1	194,100m ³	3.8 YEARS	400m
No.2	153,300m ³	3.0 YEARS	520m
No.3	157,400m ³	3.1 YEARS	430m
TOTAL	504,800m ³	9.9 YEARS	

STORAGE CAPACITY BASED ON DISPOSAL HEIGHT OF 12m

CANADIAN SALT COMPANY
UNDERGROUND TAILINGS DISPOSAL
PROPOSED DISPOSAL AREAS - 630 LEVEL

(AFTER R.C. BOEHNER)



6.0 COST ESTIMATES

Preliminary estimates of costs have been prepared to the level of detail indicated by the task. To assess cost, we have used a variety of methods such as reference to Means Cost Data, contractor budget estimates and inhouse knowledge of similar work.

These costs are summarized on Table. 6.1. We have also calculated an average annual cost based upon an amortization period of ten years at 10% interest.

In the case of the tailings deposition scheme there is very little capital cost associated with the new system of stacking. Annual costs were therefore estimated to cover expected operating charges. Conversely, charges recommended for the Hotwell diversion will be essentially all capital in nature, with the operating charges simply for pumping.

We have prepared a summary of operating costs for the underground tailings depositional schemes which has been extracted from published data.

Tailings Stacking Costs

The estimated cost for stacking the mine tailings is detailed below.

Front End Loader (2¼ yd ³ (1.7 m ³))	\$1.40 per tonne
Trucking (12 yd ³ (9m ³) Tandem)	\$1.40 per tonne
Bulldozer (D4 Type)	\$0.70 per tonne
Personnel Costs	\$0.35 per tonne
TOTAL:	\$3.85 per tonne

This estimate is based on average annual quantities of 90,000 tonnes per year. The scheduling of the stacking operation may influence the costs. The cost should, however, range between \$3.00 and \$4.00 per tonne of tailings moved.

Low Height Perimeter Dyke

The starter perimeter dyke will be in the order of 500 m (1600 ft) long with a volume of about 1,600 m³ (2000 yd³). Based on the "Means" unit rates and local contractors rates, it is expected that the dyke will be constructed within about 10 days at a cost of between \$5,000 and \$6,000 using a D4 type bulldozer.

TABLE 6.1: CAPITAL COST SUMMARY

COST ELEMENT	CAPITAL COSTS			
	CAPITAL ITEM	Total	Amortized Cost Note 1	Unit Cost per tonne tailings
No. 1 Brine Pond Overflow and Discharge	Equipment and Installation	\$50,000		
	Total	\$50,000	\$8,137	\$0.09
No. 2 Hot Well Discharge				
	Option No. 1			
	Equipment and Installation	\$86,000		
	Total	\$86,000	\$13,996	\$0.16
	Option No. 2			
	Equipment and Installation	\$230,000		
	Total	\$230,000	\$37,431	\$0.42
No. 3 Breach Repair	Equipment and Installation	\$105,000		
	Total	\$105,000	\$17,088	\$0.19
No. 4 Deep Cove Tailings	Equipment and Installation	NA	Note 2	Note 3
	Total	\$0	\$347,000	\$3.85
No. 5 Underground Tailings Disposal				
	Unthickened Tailings			
	Equipment and Installation	\$462,000		
	Total	\$462,000	\$75,188	\$0.84
	Thickened Tailings			
	Equipment and Installation	\$441,000		
	Total	\$441,000	\$71,771	\$0.80

Note 1: Ammortized over a 10 year period at 10% interest

Note 2: Capital costs not applicable, annual operating cost shown.

Note 3: Cost per tonne, based on 90,000 tonnes per year.

**TABLE 6.2: BRINE POND OVERFLOW AND HOT WELL DISCHARGE
DETAILED CAPITAL COST ESTIMATE**

Description	Units	Cost/Unit	Cost	Estimated Cost
BRINE POND OVERFLOW DISCHARGE				
Installation as illustrated on drawings 7583-11, 12 inclusive of all material equipment and labour (Based on cost estimate provided by contractor)			\$50,000	
TOTAL CAPITAL COST			\$50,000	\$50,000

HOT WELL DISCHARGE				
<u>Option No. 1:</u>				
Diversión of Pipework into Existing Sump under Settling Tank			\$10,000	
New Slurry Pump (50 HP)	1 Pump	\$15,000	\$15,000	
Control System	1 Unit	\$8,000	\$8,000	
Transfer Pipeline (6" Diameter)	720 Ft	\$62.50	\$45,000	
Contingency @ 10%			\$7,800	
TOTAL CAPITAL COST OPTION NO. 1			\$85,800	\$86,000
<u>Option No. 2:</u>				
Diversión of Pipework into Existing Sump under Settling Tank			\$2,000	
New Slurry Pump (7.5 HP)	1 Pump	\$5,000	\$5,000	
Control System	1 Unit	\$7,000	\$7,000	
Transfer Pipeline (4" Diameter)	720 Ft	\$58.33	\$42,000	
New Settling tank Foundations			\$15,000	
New Settling Tank & Support Framework*			\$116,000	
New Transfer Pump at Dissolver (20 HP)	1 Pump	\$10,000	\$10,000	
New Pipework & Modifications at Dissolver			\$10,000	
Resite Propane Tank			\$2,000	
Contingency @ 10%			\$20,900	
TOTAL CAPITAL COST OPTION NO. 2			\$229,900	\$230,000

- * New Tank
- Mild steel \$116,000
 - Rubbercoat inside walls \$118,800
 - 316 stainless \$220,000

1 inch = 25 mm
1 foot = 0.3048 metres
1 HP = 0.746 kilowatts

TABLE 6.2: BREACH REPAIR AND MODIFICATION TO EXISTING DAM
DETAILED CAPITAL COST ESTIMATE

Description	Units	Cost/Unit	Cost	Estimated Cost
Foundation Excavation				
Removal of Spoil	3475 Yd3	\$2.24	\$7,784	
Buildover	48 Hr	\$98.54	\$3,208	\$11,000
Borrow Pit Operations				
Excavate Spoil and Load Trucks	3704 Yd3	\$2.57	\$9,519	
Backhoe	8 Hr	\$83.98	\$672	
Buildover	8 Hr	\$98.54	\$536	\$11,000
Haul, Place and Compact Fill				
Haul Fill, 1/2 Mile Round Trip	3704 Yd3	\$3.24	\$12,001	
Place and Compact Fill	3047 Yd3	\$2.56	\$7,803	\$20,000
Culvert Details				
36" Class 3 Concrete Pipe	80 Ft	\$42.75	\$3,420	
72" Precast Manhole Inlet	1 Unit	\$3,280	\$3,280	
Installation	1 Unit	\$3,000	\$3,000	
Cast in Place Headwall	1 Unit	\$2,500	\$2,500	\$12,000
Filter Fabric and Riprap				
Filter Fabric	690 Yd2	\$1.29	\$890	
Riprap	480 Yd3	\$18.00	\$7,280	\$8,000
Mobilize and Demobilize				
Backhoe, Crawler Mounted	1 Unit	\$280	\$280	
Buildover	1 Unit	\$280	\$280	
Vibrating Roller, Self Propelled	1 Unit	\$280	\$280	\$1,000
Geotechnical Inspection				
Technician	100 Hr	\$43.28	\$4,328	\$4,000
Subtotal:			\$27,348	
Construction Management (@ 5% of Subtotal):			\$3,380	
Contingency (@ 10% of Subtotal plus Management):			\$7,078	\$10,000
Total Estimated Costs for Breach Repair:			\$77,833	\$77,000
Modifications to Existing Dam				
Excavate, Place and Compact Fill	1080 Yd3	\$8.37	\$9,780	
Place and Compact Granular Weir Course	874 Yd3	\$22.90	\$15,185	\$24,000
Subtotal:			\$24,964	
Construction Supervision (@ 5% of Subtotal)			\$1,198	
Contingency (@ 10% of Subtotal plus Supervision):			\$2,515	\$4,000
Total Estimated Costs for Modification to Existing Dam:			\$27,898	\$28,000
TOTAL ESTIMATED CAPITAL COSTS:			\$198,499	\$105,000

1 inch = 25 mm
1 foot = 0.3048 meters
1 Yard³ = 0.8361 m³
1 Yard² = 0.7646 m²

**TABLE 6.4: UNDERGROUND TAILINGS DISPOSAL
THICKENED TAILINGS OPTION - CAPITAL COST ESTIMATE**

Description	HP, Length or Unit	Cost/Unit	Purchase Cost	Installation Cost	Capital Cost	Estimated Costs
Hydrocyclones	2 Units	\$2,570	\$5,140	\$2,570	\$7,710	\$8,000
Thickener	1 Unit	\$182,200	\$182,200	\$91,100	\$273,300	\$273,000
Pumps						
Hydrocyclone U/F to Shaft	5 HP	\$3,400	\$3,400	\$1,700	\$5,100	
Hydrocyclone O/F to Thickener	20 HP	\$5,203	\$5,203	\$2,602	\$7,805	
Brine Return Pump	75 HP	\$12,736	\$12,736	\$6,368	\$19,104	\$32,000
Pipe Lines						
Hydrocyclone to Shaft	420 Ft @ 4"	\$4.52	\$1,898	\$759	\$2,658	
Shaft Tailings Line	630 Ft @ 4"	\$35.40	\$22,302	\$15,611	\$37,913	
630 Level Tailings Line	2000 Ft @ 4"	\$4.52	\$9,040	\$3,616	\$12,656	
630 Level Brine Return Line	2000 Ft @ 3"	\$2.70	\$5,400	\$2,160	\$7,560	
Shaft Brine Return Line	630 Ft @ 3"	\$23.90	\$15,057	\$10,540	\$25,597	
Surface Brine Disposal Line	500 Ft @ 3"	\$2.70	\$1,350	\$540	\$1,890	\$88,000
Contingency @ 10%					\$40,129	\$40,000
Total Estimated Costs:				\$137,566	\$401,293	\$441,000

1 inch = 25 mm
1 foot = 0.3048 metres
1 HP = 0.746 kilowatts

Unit Costs Based on 90,000 Tonnes per Year:

Capital Cost (Amortized at 10% Over 10 Years):	\$0.80
Operating Cost:	\$3.50
Total Cost:	\$4.30 per tonne

TABLE 6.5: UNDERGROUND TAILINGS DISPOSAL
UNTHICKENED TAILINGS OPTION - CAPITAL COST ESTIMATE

Description	HP, Length or Unit	Cost/Unit	Purchase Cost	Installation Cost	Capital Cost	Estimated Cost
<u>Pumps</u>						
Mill to Shaft	60 HP	\$14,520	\$14,520	\$7,260	\$21,780	\$140,000
Brine Return Pump	1300 HP	\$78,800	\$78,800	\$39,400	\$118,200	
<u>Pipe Lines</u>						
Mill to Shaft	420 Ft @ 8"	\$12.18	\$5,116	\$2,046	\$7,162	
Shaft Tailings Line	630 Ft @ 8"	\$78.00	\$49,140	\$34,398	\$83,538	
630 Level Tailings Line	2000 Ft @ 8"	\$12.18	\$24,360	\$9,744	\$34,104	
630 Level Brine Return Line	2000 Ft @ 10"	\$16.87	\$33,740	\$13,496	\$47,236	
Shaft Brine Return Line	630 Ft @ 10"	\$89.50	\$56,385	\$39,470	\$95,855	
Surface Brine Disposal Line	500 Ft @ 10"	\$16.87	\$8,435	\$3,374	\$11,809	\$280,000
Contingency @ 10%					\$41,968	\$42,000
Total Estimated Costs:			\$270,496	\$149,188	\$481,652	\$482,000

1 inch = 25 mm
1 foot = 0.3048 metres
1 HP = 0.746 kilowatts

Unit Costs Based on 90,000 Tonnes per Year:

Capital Cost (Amortized at 10% Over 10 Years)	\$0.84
Operating Cost:	\$3.50
Total Cost:	\$4.34 per tonne

TABLE 6.6 RANGE OF TYPICAL BACKFILLING OPERATING COSTS

Mine	Tons Fill Per Day (Tons)	U/G Prod. Per Day (Tons)	Backfilling Cost/Ton Production	Backfilling Total Cost Per Day	Operating Cost/Ton Backfill
Belmoral Mines Ltd.	600	1,275	\$1.28	\$1,632	\$2.72
Canamax, Ketz River	200	200	\$2.07	\$414	\$2.07
Dickenson Mines	450	965	\$4.11	\$3,966	\$8.81
Hudson Bay, Rod Mine	93	511	\$2.24	\$1,145	\$12.31
INCO Thompson	3,050	6,000	\$1.50	\$9,000	\$2.95
Kiena Gold Mine	1,200	1,900	\$3.54	\$6,726	\$5.61
Mines Selbale	500	2,120	\$2.14	\$4,537	\$9.07
Noranda Minerals					
Gaspé Division	1,900	3,000	\$3.52	\$10,560	\$5.56
Mattagami Lake	600	1,250	\$2.39	\$2,968	\$4.98
Placer Dome					
Campbell Mine	900	1,500	\$3.46	\$5,190	\$5.77
Detour Lake	1,380	2,530	\$1.41	\$3,567	\$2.59
Dome Mine	1,000	4,200	\$3.40	\$14,280	\$14.28
Teck Corona					
David Bell Mine	520	1,100	\$5.56	\$6,116	\$11.76
Westmin Canada					
Copper Rand	550	1,475	\$1.43	\$2,109	\$3.84
Portage Mine	540	1,000	\$2.74	\$2,740	\$5.07
Westmin Resources					
HW Mine	1,650	3,325	\$6.00	\$19,950	\$12.09
MAXIMUM COST:					\$14.28
MINIMUM COST:					\$2.59
MEAN COST:					\$6.84

This table provides a cost range for backfilling at 16 Canadian mining operations. It is expected that underground disposal of salt tailings at Pugwash would range between \$3.00 and \$4.00 per tonne.

Source: Mining Source Book, 1989, 1990, 1991

1 ton = 0.91 tonnes

7.0 REFERENCES

Kaufmann, D.W., 1960: Sodium Chloride, American Chemical Society, Monograph Series No. 145, Reinhold Publishing Corporation, New York

Boehner, R.C., 1986: Salt and Potash Resources in Nova Scotia, Bulletin 5, Nova Scotia Dept. of Mines and Energy.

Vaughan, J.G., 1980: Regional Water Resources, Cumberland County, Nova Scotia., Nova Scotia Dept. of the Environment.

Environment Canada, 1980: Canadian Climate Normals, 1951-1980, Temperature and Precipitation, Atlantic Provinces.



Appendix A

Environmental Control Program
Departmental Communication



Nova Scotia

**Department of
the Environment**

Office of the Minister

PO Box 2107
Halifax, Nova Scotia
B3J 2M7

Our file no. 11-91-0016
04-91-0002

JUL 25 1991

Mr. William McCormick, Manager
The Canadian Salt Company Ltd.
Pugwash Mine & Refinery
P. O. Box 160
Pugwash, N. S.
B0K 1L0

Dear Mr. McCormick:

Re: Environmental Control Program

Staff of the Nova Scotia Department of the Environment, Fisheries and Oceans, and Environment Canada have recently inspected and reviewed existing conditions at the Pugwash Mine and Refinery in Cumberland County. As a result of this consultation with the regulatory agencies and consideration of your application of an Industrial Permit, it has been determined that it is not currently in the province's best interest to issue a permit at this time.

The Nova Scotia Department of the Environment requires that the Canadian Salt Company Limited submit details of a Control Program to achieve the following goals of effluent discharge consistent with Sections 10 through 13 of the Environmental Protection Act, RSNB, 1989:

1. submit an engineering plan by January 1, 1992 for existing and future disposal of tailings waste, including containment of solid tailings waste to ensure deposited tailings are uninfluenced by tidal action.
2. submit an engineering plan by November 1, 1991 to deposit solid and liquid waste currently associated with the Hotwell Discharge into the new tailings disposal system referred to above.
3. submit an engineering plan by January 1, 1992 to pipeline and diffuse liquid effluent into Pugwash Basin and demonstrate minimal environmental impacts.

- 2 -

4. submit an engineering plan by November 1, 1991 to prevent discharge from the brine holding lagoon into Pugwash Basin.

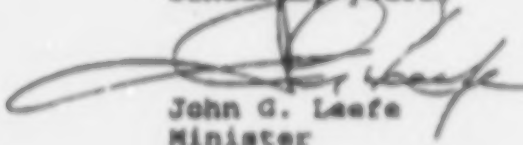
I have included names of consultants listed by the Nova Scotia Consulting Engineers Association as having tailings disposal as a field of practice.

Consultants

Acres International Limited
Beasy Nicoll Engineering Limited
Jacques, Whitford and Associates Limited
Nolan Davis and Associates (N.S.) Ltd.
Porter Dillon Ltd.
UMA Engineering Ltd.
Vaughan Engineering Associates Ltd.

Should there be any questions concerning this environmental control program please contact Mr. Bernie Matlock, P. Eng., of the Industrial Pollution Control section at 424-5100.

Sincerely yours,



John G. Laefe
Minister

Appendix B

Geotechnical Investigation

**CANADIAN SALT COMPANY LIMITED
GEOTECHNICAL INVESTIGATION
PUGWASH, N.S.
PROJECT NO. 7583**



PROJECT NO. 7583

REPORT TO

CANADIAN SALT COMPANY LIMITED

ON

GEOTECHNICAL INVESTIGATION

CANADIAN SALT COMPANY LTD.

PUGWASH, N.S.

Jacques, Whitford and Associates Limited
January 31, 1992



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Appendix 1

- Summary of 1991 Borehole Program
- Symbols and Terms Used on Borehole and Test Pit Records
- Borehole Records

Appendix 2

- Summary of Laboratory Tests
- Grain Size Distribution Curves

Appendix 3

- Drawing 7583-1: Effluent Control/, Geotechnical Investigation



1.0 INTRODUCTION

Jacques, Whitford and Associates Limited, acting at the request of Mr. Alan Davidson, P.Eng., of the Canadian Salt Company Limited, has carried out a geotechnical investigation at the site of a tailings pond at the company's salt mining facility in Pugwash, Nova Scotia. The purpose of the investigation was to obtain the geotechnical information required for the design of a replacement of a portion of a dam for a tailings pond. All relevant information obtained is reported herein.

2.0 SITE AND GEOLOGY

The Canadian Salt Company Limited salt mine at Pugwash is located in the town of Pugwash, situated along the Northumberland Strait on the northern shore of Nova Scotia. The mine site is adjacent to the Pugwash River, which experiences a normal tidal influence of 1.8 to 2.4 metres (6 to 8 feet).

The topography of the area is gently undulating with local relief up to 15 metres (50 feet), covered by forest. Geological maps of the area indicate that bedrock is gypsum, anhydrite, limestone, dolostone and halite of the Windsor Group.

A tailings pond was constructed at the site several years ago by building an earthen dam about 366 metres (1200 feet) long and 3 metres (10 feet) high across Deep Cove, a small cove on the shoreline of the river. The original dam was terminated in a tailings waste fill zone at its northern end. After a number of years, the fill was washed away by tidal action, precipitation and the tailings discharge, resulting in a breach in the dam about 15 metres (50 feet) wide.

3.0 PROCEDURES

The field work was carried out from 21 October to 23 October, 1991. A summary of the program is presented in Table 1.1. Seven boreholes were drilled along two cross sections across the breach. Two of the boreholes were located on the dam, four on the tailings fill, and one at the bottom of the gully. The locations of the boreholes are shown on Drawing No. 7583-1, Appendix 3.

The boreholes were executed with 100 mm (4 inch) flight augers to depths of 5.6 to 9.5 metres (3 to 31.0 feet). The soils were sampled at intervals of approximately 1.2 m (4 ft) using a 50 mm (2 inch) OD split spoon sampler. Bedrock was not encountered at any of the test locations. Detailed logs of the soils encountered, and the sampling and testing carried out, are given on the Borehole Records in Appendix 1.

All soil samples were returned to our Dartmouth laboratory for further examination and testing. Samples will be stored for a period of six months, until April 1992, at which time you will be contacted for instructions concerning their disposal.

Actual borehole locations were chosen by our field personnel based on site conditions and accessibility. The locations and elevations of the boreholes have been established by personnel from Jacques Whitford and the Canadian Salt Company Ltd., and are referenced to Geodetic datum.

4.0 BOREHOLE PROGRAM RESULTS

The findings of this investigation are fully described on the Borehole Records in Appendix 1, and summarized in this section.



4.1 Tailings waste fill

A varying fill layer of white and grey tailings waste with some anhydrites and traces of gypsum was encountered at the surface in Boreholes 4 through 7. The thickness of the fill ranged from 2.9 m (9.5 ft) in Borehole 4 to 5.5 m (18 ft) in Borehole 7. The top 0.3 (1 ft) was generally more dense due to natural cementation caused by exposure. A crust has formed over much of the fill, with voids immediately below in places.

Split spoon tests below the first foot indicate that most of the fill has a relative density classified as very loose. Occasional voids were encountered during drilling in this layer. A zone in Borehole 7 from 1.2 to 3 m (4 to 10 ft) in was found to be in a dense state.

4.2 Gypsum and gravel fill

A layer of loose to dense brown gypsum and gravel with some sand and traces of rootlets, wood and other debris was encountered in Borehole 6. The layer was 2.1 m (7 ft) thick, and underlay the tailings waste fill.

4.3 Intermixed fill

A two foot layer of soft brown silty sand and gravel fill, intermixed with coal, black silt and peat was found to underlay the tailings waste fill in Borehole 5. The peat was similar to that described above.

4.4 Sandy silty clay fill

Reddish brown sandy silty clay fill with trace to some gravel, traces of rootlets and occasional small pockets of brown sand was encountered at the surface of Boreholes 1, 2 and 3, and below the intermixed fill in Borehole 5. The fill was 1.4 m (4.5 ft) thick in Borehole 5, 2.1 m (7 ft) in Borehole 1, and 5.5m (18 ft) and 7.3 m (24 ft) thick in

Boreholes 2 and 3, respectively. The clay fill forms the majority of the material used to construct the dam, and is essentially identical to the local till material, except that it has been moved or reworked. The consistency of the fill in the dam was soft to stiff.

A zone of the fill in Borehole 2 from 5.5 to 9.1 m (18 ft to 30 ft) had a higher gravel content, with half of the gravel being white gypsum. A water content analysis performed on a sample from this zone yielded a moisture content of 24 percent.

4.5 Sandy silt

A layer of brown and grey organic sandy silt was encountered below the gypsum and gravel fill in Borehole 6. The material displayed a consistency from soft to firm, a moderately organic odour, and a thickness of about 1.5 m (5 ft). The silt appears to be a natural alluvial deposit existing prior to the development of the site.

4.6 Peat

A layer of brown fibrous peat was encountered below the sandy silt layer in Borehole 6. The material also had a consistency from soft to firm, a strong organic odour, and a thickness of about 1.7 m (5.5 ft). The peat is indicative of a pre-existing marsh or swamp at the site.

4.7 Sandy silty clay till

All boreholes, with the exception of Borehole 2, were terminated in a stratum of reddish brown sandy silty clay till with trace to some gravel and occasional small pockets of brown sand. The till was penetrated to thicknesses between 1.5 ft in Borehole 6 and 19 ft in Borehole 1. The consistency varied from firm to very stiff, generally increasing in stiffness with depth.

Two grain size distribution analyses conducted on the material, using the procedure described in ASTM D-422, showed a fair degree of consistency, with 4 percent and 15 percent gravel, 29 percent and 28 percent sand, and 67 percent and 57 percent silt and clay-size particles.

The four moisture content analyses performed on the material lie within a relatively narrow band from 12 to 18 percent, with the average of 15 being just below the plastic limit of the material. An Atterberg limits test yielded a liquid limit of 29, and a plastic limit of 16. With a corresponding plasticity index of 13, the soil is classified as an inorganic clay of low to medium plasticity.

5.0 CLOSING COMMENTS

We have presented the field and laboratory data from the investigation in order to characterize the present site conditions; however, we caution that a geotechnical investigation is a random sampling of a site, and we require that we be notified of any site conditions which differ from those at borehole locations.

Field work for this project was completed under the supervision of Mr. Brian Walsh, E.I.T. This report has been prepared by Mr. Walsh and Mr. Brian Taylor, P.Eng.

Respectfully submitted,

JACQUES, WHITFORD AND ASSOCIATES LIMITED



Brian B. Taylor, Ph.D., P.Eng.

J. Brian Walsh, E.I.T.

SYMBOLS AND TERMS USED ON THE BOREHOLE AND TEST PIT RECORDS

SOIL DESCRIPTION

Behavioural properties (i.e. plasticity, permeability) take precedence over particle gradation in describing soils.

Terminology describing soil structure:

Decicated	-	Having visible signs of weathering by oxidation of clay minerals, shrinkage cracks, etc.
Fractured	-	Having cracks, and hence a blocky structure
Varved	-	Composed of regular alternating layers of silt and clay
Stratified	-	Composed of alternating layers of different soil types, e.g. silt and sand or silt and clay
Well Graded	-	Having wide range in grain sizes and substantial amounts of all intermediate particle sizes
Uniformly Graded	-	Predominantly of one grain size

Terminology used for describing soil strata based upon the proportion of individual particle sizes present:

Trace, or occasional	less than 10%
Some	10-20%
Adjective (e.g. silty or sandy)	20-35%
And (e.g. silt and sand)	35-50%

The standard terminology to describe cohesionless soils includes the relative density, as determined by laboratory test or by the Standard Penetration Test (N) value: the number of blows of 140 pound (64kg) hammer falling 30 inches (762mm), required to drive a 2 inch (50.8mm) O.D. split spoon sampler one foot (305mm) into the soil.

Relative Density	N Value	Relative Density %
Very Loose	<4	<15
Loose	4-10	15-35
Compact	10-30	35-65
Dense	30-50	65-85
Very Dense	>50	>85

The standard terminology to describe cohesive soils includes the consistency, which is based on undrained shear strength as measured by vane tests, penetrometer tests, unconfined compression tests, or occasionally by standard penetration tests.

Consistency	Undrained Shear Strength		N Value
	kips/sq ft	kPa	
Very Soft	<0.25	<12.5	<2
Soft	0.25-0.5	12.5-25	2-4
Firm	0.5-1.0	25-50	4-8
Stiff	1.0-2.0	50-100	8-15
Very Stiff	2.0-4.0	100-200	15-30
Hard	>4.0	>200	>30



SYMBOLS AND TERMS CONTINUED

STRATA PLOT



Gravel &
boulders



Sand



Silt



Clay



Fill



Unconsolidated
bedrock



Consolidated
bedrock



Metamorphic
bedrock

WATER LEVEL MEASUREMENT



Borehole or
standpipe



Piezometer

SAMPLES

- SS... Split spoon sample
obtained by performing the
standard penetration test
ST... Shelby tube or thin
wall tube
PS... Piston sample

- BS... Bulk sample
WS... Wash sample
RC... Rock core
AXT, BXL, etc...
Rock core samples obtained
with the use of standard
diamond drilling bits.

OTHER TESTS

- G... Specific gravity
H... Hydrometer analysis
S... Sieve analysis
Y... Unit weight
C... Consolidation
CD... Consolidated drained
triaxial

- CU... Consolidated undrained
triaxial with pore
pressure measurements
UU... Unconsolidated undrained
triaxial
Ds... Direct shear
P... Field permeability

ROCK DESCRIPTION

The description of bedrock is based on the rock quality designation (RQD).

The classification is based on a modified core recovery percentage in which all pieces of sound core over 100mm long are counted as recovery. The smaller pieces are considered to be due to close shearing, jointing, faulting, or weathering in the rock mass and are not counted. In most cases RQD is run on NAL core; however, it can be used on different core sizes if the bulk of the fractures caused by drilling stresses are easily distinguishable from normal *in situ* fractures.

RQD

90-100
75-90
50-75
25-50
0-25

ROCK QUALITY

Excellent, intact, very sound
Good, massive, moderately jointed or sound
Fair, blocky and seamy, fractured
Poor, shattered and very seamy or blocky,
severely fractured
Very poor, crushed, very severely fractured.



BOREHOLE RECORD

1

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 7583LOCATION PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 1DATE: BORING 91/10/21

WATER LEVEL _____

D.C./M. GEOTECH

DEPTH (FT.)	ELEVATION (FT.)	SOIL DESCRIPTION	STRATA	PLOT	WATER LEVEL	SAMPLES					UNDRAINED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBERG LIMITS		DYNAMIC PENETRATION TEST, BLows/ft	STANDARD PENETRATION TEST, BLows/ft
						TYPE	NUMBER	RECOVERY	IN-LABOR OR RGD	OTHER TESTS	20	40	60	80	Wp	U		
0	3.9																	
1		Dense to compact reddish brown sandy gravelly silt with trace clay and wood: FILL.				SS	1	10	39									
2																		
3																		
4																		
5						SS	2	4	12									
6																		
7	-3.1																	
8		Firm to stiff reddish brown sandy silty clay with trace gravel: TILL.				SS	3	10	6									
9		-occasional pockets of brown sand																
10		-plasticity increases with depth																
11																		
12																		
13						SS	4	8	7									
14																		
15																		
16																		
17						SS	5	9	30 for 6'									
18																		
19																		
20																		
21						SS	6	9	10									
22																		
23																		
24																		
25						SS	7	11	10									
26	-22.1																	
27		End of Borehole																
28		NOTE: water level tidal																
29																		
30																		
31																		
32																		
33																		
34																		
35																		



BOREHOLE RECORD

2

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 1983LOCATION PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 2DATE LOGGING 91/10/21

WATER LEVEL

DATUM GEODETIC

DEPTH (ft)	ELEVATION (ft)	SOIL DESCRIPTION	STATION PLAT	WATER LEVEL	SAMPLES					UNRAINED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBERG LIMITS			DYNAMIC PENETRATION TEST, BLows/ft	STANDARD PENETRATION TEST, Blows/ft
					TYPE	NUMBER	RECOVERY	W-LIME OR BAGO	OTHER TESTS	20	40	60	80	Ip	U	W _L		
0	10.6	Firm becoming stiff reddish brown sandy silty clay with trace gravel and rootlets: FILL.																
1					SS	1	6	5										
2																		
3																		
4																		
5		Firm becoming stiff reddish brown sandy silty clay with trace gravel and rootlets: FILL.			SS	2	7	17										
6																		
7																		
8																		
9					SS	3	5	7										
10		Firm becoming stiff reddish brown sandy silty clay with trace gravel and rootlets: FILL.																
11																		
12																		
13																		
14					SS	4	10	17										
15		Firm becoming stiff reddish brown sandy silty clay with trace gravel and rootlets: FILL.																
16																		
17																		
18																		
19	-7.4				SS	5	11	10										
20		Stiff reddish brown sandy silty clay with some gravel: FILL. -50 % of gravel is white gypsum																
21					SS	6	5	5										
22																		
23																		
24																		
25		Stiff reddish brown sandy silty clay with some gravel: FILL. -50 % of gravel is white gypsum			SS	7	7	9										
26																		
27																		
28																		
29					SS	8	9	9										
30	-19.4	End of Borehole NOTE: water level tidal																
31																		
32																		
33																		
34																		
35																		



BOREHOLE RECORD

3

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 7583LOCATION PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 3DATE: BORING 91/10/22

WATER LEVEL

DATUM GEODETIC

DEPTH (m)	ELEVATION (m)	SOIL DESCRIPTION	STANDA. PLAT.	WATER LEVEL	SAMPLES					UNRAINED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBERG LIMITS				DYNAMIC PENETRATION TEST, BLOW/FT	STANDARD PENETRATION TEST, BLOW/FT
					TYPE	NUMBER	RECOVERY	W-LAKE OR BOLD	OTHER TESTS	20	40	60	80	Ip	U				
0	10.7						47												
1		Soft becoming stiff reddish brown sandy silty clay with trace gravel and rootlets: FILL.			SS	1	10	5											
2		-occasional pockets of brown sand																	
3		-plasticity increases with depth																	
4					SS	2	20	8											
5																			
6																			
7																			
8																			
9					SS	3	8	4											
10																			
11																			
12																			
13					SS	4	16	15											
14																			
15																			
16																			
17					SS	5	15	11											
18																			
19																			
20																			
21					SS	6	8	16											
22																			
23																			
24	-13.3																		
25		Very stiff reddish brown sandy silty clay with trace gravel: FILL.			SS	7	14	18											
26																			
27																			
28																			
29																			
30	-19.3				SS	8	15	26											
31		End of Borehole																	
32		NOTE: water level tidal																	
33																			
34																			
35																			



BOREHOLE RECORD

4

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 7583LOCATION FUZWASH, CUMBERLAND COUNTY, NOVA SCOTIABORERHOLE No. 4DATE: BORING 91/10/22

WATER LEVEL

DATUM GEODETIC

DEPTH (FT.)	ELEVATION (FT.)	SOIL DESCRIPTION	STRATA PLLOT	WATER LEVEL	SAMPLES					UNRAINED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBERG LIMITS				DYNAMIC PENETRATION TEST, BLows/ft	STANDARD PENETRATION TEST, BLows/ft
					TYPE	NUMBER	RECOVERY	IN-LINE OR NOT	OTHER TESTS	20	40	60	80	Ip	U	L			
0	17.1																		
1		Very loose to very dense white and brown tailings waste containing halite and some gypsum: FILL. -surface material naturally cemented			SS	1	15	07											
2																			
3																			
4																			
5					SS	2	7	2											
6																			
7																			
8																			
9	7.6				SS	3	15	5											
10		Stiff reddish brown silty clay with some sand and trace gravel: TILL																	
11																			
12					SS	4	12	11											
13																			
14																			
15																			
16																			
17					SS	5	16	11											
18	-1.2																		
19		End of Borehole NOTE: water level tidal																	
20																			
21																			
22																			
23																			
24																			
25																			
26																			
27																			
28																			
29																			
30																			
31																			
32																			
33																			
34																			
35																			



BOREHOLE RECORD

5

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 798LOCATION PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 1DATE: BORING 91/10/22

WATER LEVEL

DATUM GEODETIC

DEPTH (FT.)	ELEVATION (FT.)	SOIL DESCRIPTION	STRATA PLOT	WATER LEVEL	SAMPLER					UNSATURATED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBURG LIMITS				DYNAMIC PENETRATION TEST, BLOW/FT				STANDARD PENETRATION TEST, BLOW/FT				
					TYPE	NUMBER	RECOVERY	IN-LINE OR ANG	OTHER TESTS	20	40	60	80	w _p	w _L	U _c	U _L	10	20	30	40	50	60	70	80	90
0	13.8	Very loose to dense white and brown tailings waste containing halite and some gypsum: FILL. -surface material naturally cemented					LN																			
1	SS				1	12	33																			
2																										
3																										
4																										
5								SS	2	14	2															
6																										
7																										
8																										
9					SS	3	15	4																		
10																										
11	2.8	Soft interstratified brown silty sand and gravel, coal, black silt and peat: FILL.																								
12																										
13	0.8	Soft reddish brown silty clay with some sand and trace gravel: FILL.			SS	4	17	8																		
14		Soft reddish brown silty clay with some sand and trace gravel: FILL.																								
15		-disturbed local till																								
16																										
17	-3.7	Stiff to very stiff reddish brown silty clay with some sand and trace gravel: FILL.			SS	5	19	11																		
18																										
19																										
20																										
21	-6.0	End of Borehole			SS	6	20	20																		
22		NOTE: water level tidal																								
23																										
24																										
25																										
26																										
27																										
28																										
29																										
30																										
31																										
32																										
33																										
34																										
35																										



BOREHOLE RECORD

6

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 7883LOCATION PUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 6DATE BORING 91/10/22

WATER LEVEL _____

DATUM GEODETIC

DEPTH (FT.)	ELEVATION (FT.)	SOIL DESCRIPTION	STRATA PL. LOT	WATER LEVEL	SAMPLES					UNDRAINED SHEAR STRENGTH - psf				WATER CONTENT & ATTERBERG LIMITS				DYNAMIC PENETRATION TEST, BLMS/FT		STANDARD PENETRATION TEST, BLMS/FT	
					TYPE	NUMBER	RECOVERY	W-LAKE OR BQD	OTHER TESTS	30	60	90	120	w _p	w _L	U _c					
0	13.1						1%														
1		Loose to compact white and brown tailings waste containing halite and some gypsum: FILL.			SS	1	11	19													
2																					
3																					
4						SS	2	12	8												
5																					
6																					
7																					
8																					
9					SS	3	10	3													
10																					
11	2.1																				
12		Loose to dense brown gypsum and gravel with some sand and rocklets, wood and debris: FILL.																			
13					SS	4	10	6													
14																					
15																					
16					SS	5	2	33	2												
17																					
18	-4.9																				
19		Soft to firm brown and grey organic sandy SILT -ochreous																			
20																					
21					SS	6	20	3													
22																					
23	-9.9																				
24		Soft to firm brown fibrous PEAT -ochreous																			
25					SS	7	6	6													
26																					
27																					
28	-15.4																				
29		Soft reddish brown silty clay, trace sand and gravel: TILL.			SS	8	9	12													
30	-16.9																				
31																					
32																					
33		End of Borehole NOTE: water level tidal																			
34																					
35																					



BOREHOLE RECORD

7

CLIENT CANADIAN SALT COMPANY LIMITEDPROJECT No. 7883LOCATION FUGWASH, CUMBERLAND COUNTY, NOVA SCOTIABOREHOLE No. 7DATE: BORING 91/10/22

WATER LEVEL

DATUM GEODETIC

DEPTH (FT.)	ELEVATION (FT.)	SOIL DESCRIPTION	STRATA PLAT	WATER LEVEL	SAMPLED					UNSATURATED SHEAR STRENGTH - psf								
					TYPE	NUMBER	RECOVERY	W-LABEL OR END	OTHER TESTS	20	40	60	80					
0	20.9									WATER CONTENT & ATTENDING LIMITS: w_p w_u								
1		Loose to very dense white and brown tailings containing halite and some gypsum: FILL.			SS	1	14	15		DYNAMIC PENETRATION TEST, BLANK/FT. $\bullet$								
2										STANDARD PENETRATION TEST, BLANK/FT. $\bullet$								
3										10	20	30	40	50	60	70	80	90
4																		
5					SS	2	15	46										
6																		
7																		
8																		
9					SS	3	8	40										
10																		
11	9.9																	
12		Stiff to very stiff reddish brown silty clay with trace sand and gravel: TILL.			SS	4	7	6										
13																		
14																		
15																		
16					SS	5	2	50	50									
17																		
18																		
19																		
20																		
21					SS	6	5	16										
22																		
23																		
24																		
25					SS	7	20	28										
26	-5.1																	
27		End of Borehole																
28		NOTE: water level tidal																
29																		
30																		
31																		
32																		
33																		
34																		
35																		



Appendix 2

- Summary of Laboratory Tests
- Grain Size Distribution Curves

TABLE 2.1 SUMMARY OF LABORATORY TESTING

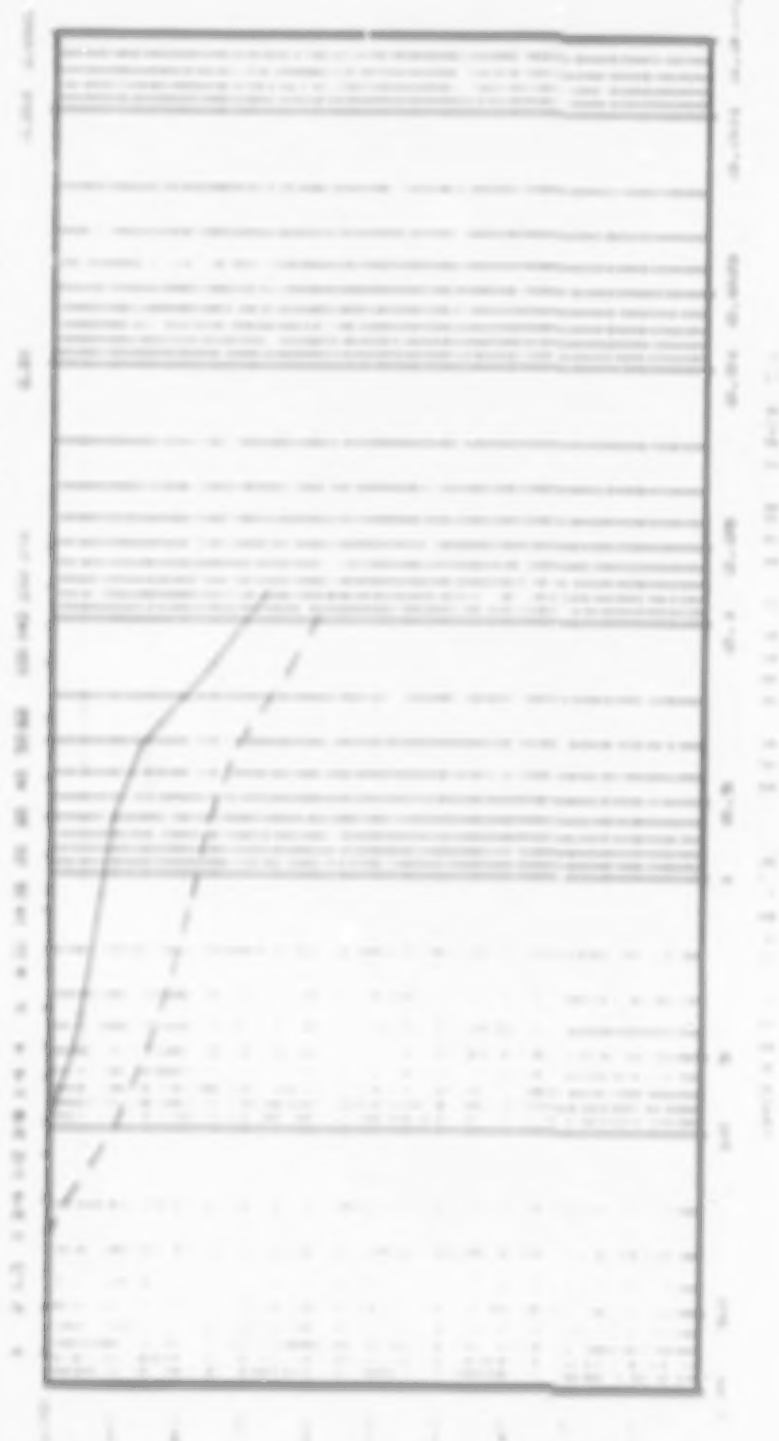
Borehole No.	Sample No.	Description	Depth (ft.)	Moisture Content (%)	Percent Gravel (%)	Percent Sand (%)	Percent Fines (%)	Liquid Limit (%)	Plastic Limit (%)
BH 1	6	Clay Till	20.0 - 22.0	18.2	4	29	67	-	-
BH 2	7	Clay Fill	23.7 - 25.7	23.7	15	26	57	-	-
BH 3	7	Clay Till	24.3 - 26.3	16.2	-	-	-	-	-
BH 4	4	Clay Till	11.3 - 13.3	14.9	-	-	-	-	-
BH 7	7	Clay Till	24.0 - 26.0	12.5	-	-	-	29	16

100' 0" 200' 0" 300' 0" 400' 0" 500' 0" 600' 0" 700' 0" 800' 0" 900' 0" 1000' 0"

100' 0" 200' 0" 300' 0" 400' 0" 500' 0" 600' 0" 700' 0" 800' 0" 900' 0" 1000' 0"

100' 0" 200' 0" 300' 0" 400' 0" 500' 0" 600' 0" 700' 0" 800' 0" 900' 0" 1000' 0"

100' 0" 200' 0" 300' 0" 400' 0" 500' 0" 600' 0" 700' 0" 800' 0" 900' 0" 1000' 0"



LOCATION	SAMPLE	DEPTH	DESCRIPTION
SA 0	SA 0	0-22.0'	Sandy Silty Clay Till
SA 7	SA 7	7-25.7'	Sandy Silty Clay Till

DEPT. 0-22.0' Sandy Silty Clay Till

DEPT. 7-25.7' Sandy Silty Clay Till



Appendix 3

- Drawing 7583-1: Proposed Cofferdam, Geotechnical Investigation





Jacques
Whitford and
Associates Limited

REPORT
BARNWORTH AND ROBERTS SURVEYS LTD.
No. E-1576, DATED 91/06/28
REVISION 1, DATED 1992/01/02
PREVIOUSLY ISSUED AS PROPOSED
OFFER SHEET

SCALE: 1" = 100'
DATE: 91/10/28
DRAWN BY: D. BAKER
CHECKED BY: [Signature]

CANADIAN SALT MINE COMPANY LIMITED
**EFFLUENT
CONTROL**
PUGWASH, CUMBERLAND COUNTY, N.S.

GEOTECHNICAL
INVESTIGATION

PROJECT NO.

7583-1

Appendix C

Brine Pond Overflow Discharge



**Jacques
Whitford and
Associates Limited**

Consulting Engineers
and Scientists

Jacques Whitford Building
Spectacle Lake Drive
Dartmouth, Nova Scotia
B2B 1W8

TEL: 902 468 7777
FAX: 902 468 9009

Electrical Engineering
Environmental Engineering
General Engineering
Mechanical Engineering
Process Engineering
Structural Engineering

Process Engineering, Research
and Development
Production
Construction Services
Construction Management

Dartmouth, NS
Halifax, NS
Port Hawkesbury, NS
Saint John, NB
Fredericton, NB
Moncton, NB
Bathurst, NB
Charlottetown, PEI
St. John's, NF
Corner Brook, NF
Montreal, PQ
Ottawa, ON
Toronto, ON

File No. 7583

January 31, 1992

Mr. Alan Davidson, Evaporator Plant Superintendent
The Canadian Salt Company Ltd.
Pugwash Mine & Refinery
P.O. Box 160
Pugwash, N.S.
B0K 1L0

Dear Alan:

This letter accompanies two copies of our draft report concerning effluent control at the Pugwash Mine site in accordance with our arrangements.

Our report represents the findings and statement of general conclusions relative to all of the effluent control issues that had been identified in your original request for proposal with subsequent amendments following your verbal and written instructions. We have specifically addressed:

- Brine Pond Over Flow
- Hotwell Discharge
- Repair of Tailings Area Breach
- Tailings Disposal Program
 - Existing Area
 - Alternate Areas
 - Underground Disposal

The report is being filed in draft for the purpose of Corporate review prior to submission of all or part of the report to the Government at the end of February 1992. You have advised that following your in-house review, you will likely require a review meeting to be scheduled towards the middle of February at either Halifax or Pugwash.

File 7583

Page 2

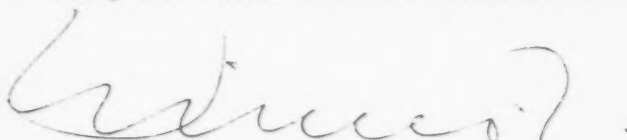
January 30, 1992

In accordance with your instruction, I have forwarded two copies of the draft report directly to Dave Kirpatrick in Chicago and Guy LeBlanc in Montreal. Mike Waterfield has also received a copy and has been asked for comments.

It has been a pleasure working with you and the Canadian Salt Company on this assignment and we trust that our draft report will meet with your approval. We thank CSCL for the opportunity to conduct this work on its behalf.

Yours very truly,

JACQUES. WHITFORD AND ASSOCIATES LTD.



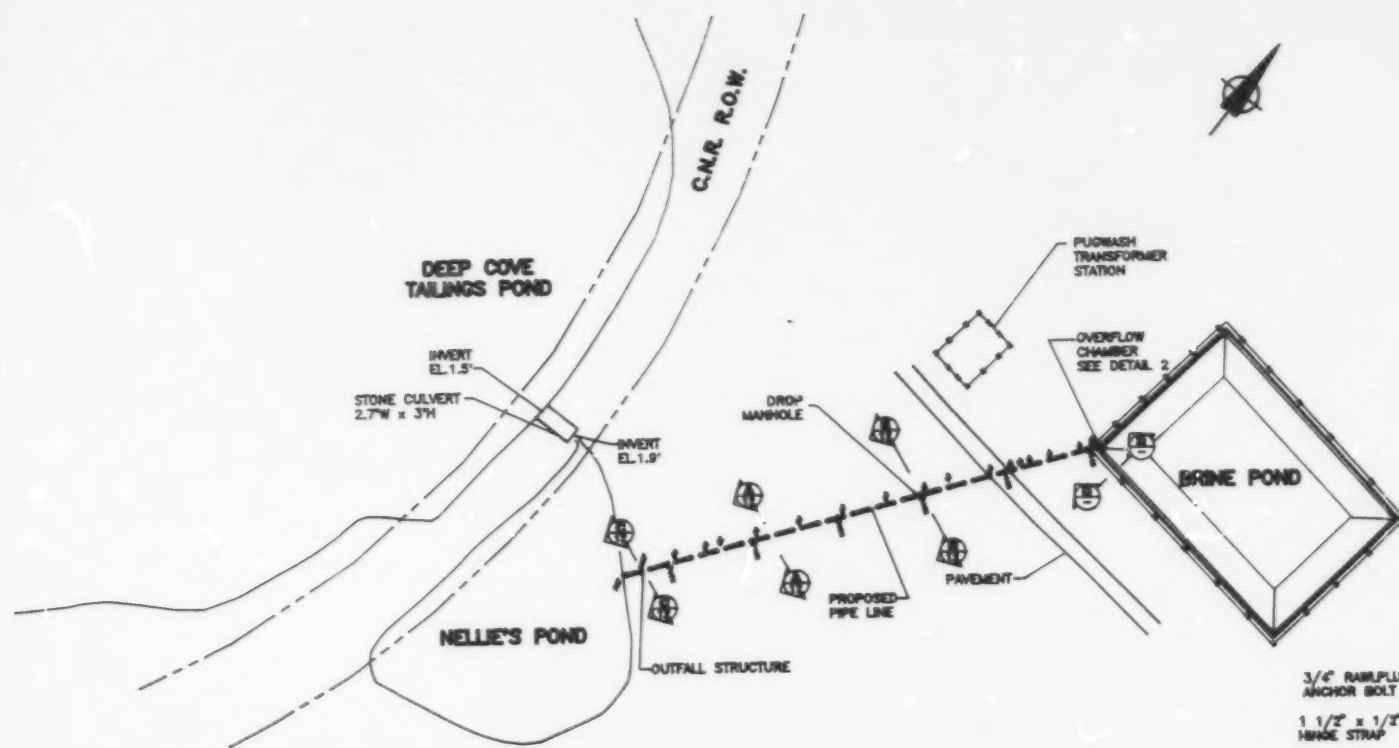
John A. Amirault, M.Eng., P.Eng.
Vice President, Mining

cc: William McCormick - Canadian Salt Mine in Pugwash
Dave Kirpatrick - Chicago
Guy Leblanc - Montreal
Mike Waterfield

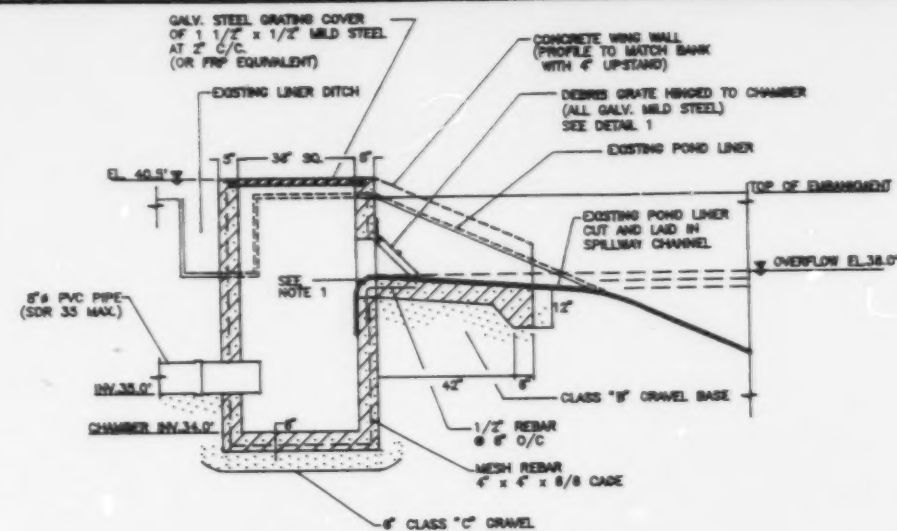
JAA/tdr



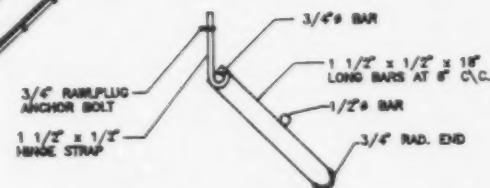




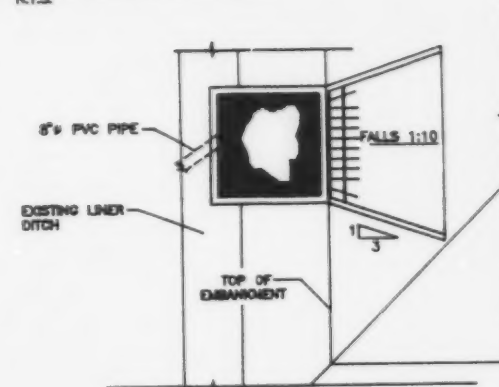
PLAN
SCALE: 1" = 200'



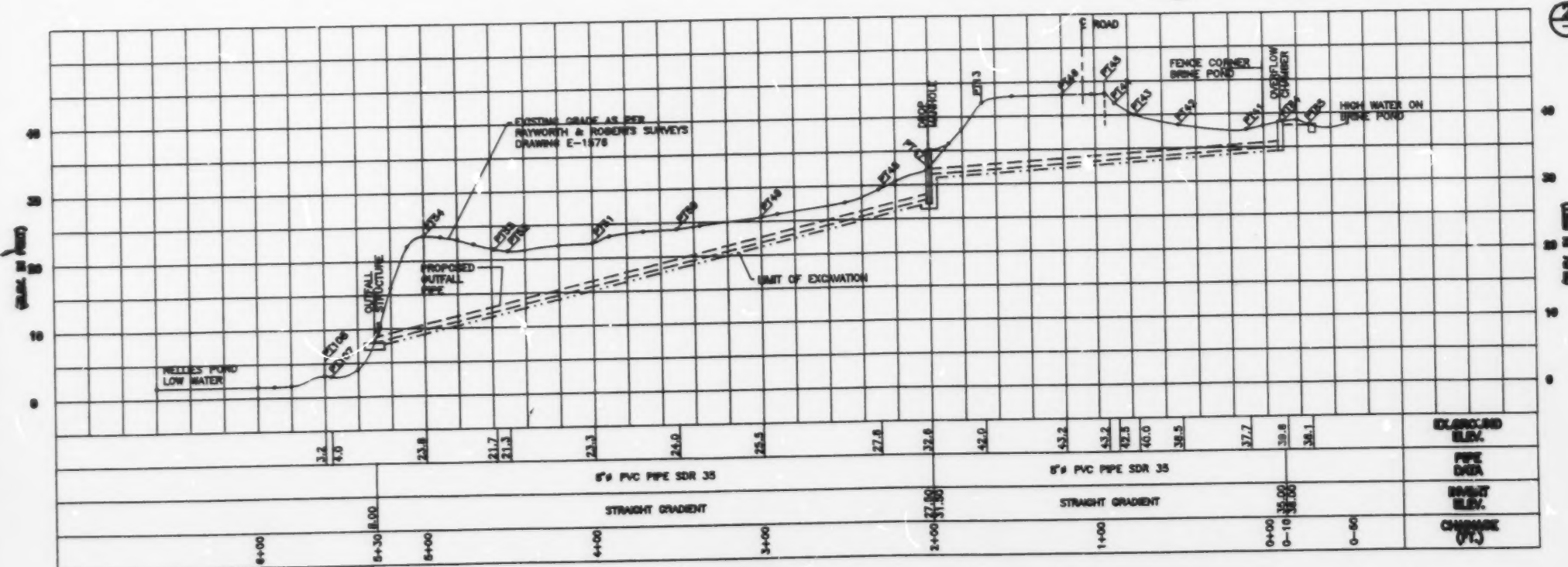
SECTION THROUGH OVERFLOW CHAMBER
N.T.S.



DEBRIS GRATE DETAIL
N.T.S.



PLAN OF OVERFLOW CHAMBER
N.T.S.



PROFILE
SCALE: 1" = 20' HORIZ.
1" = 10' VERT.

LEGEND:

SURVEY POINTS TAKEN FROM
RAYWORTH & ROBERTS SURVEY
DRAWING E-1578.

GENERAL NOTES:

1. REF. DRAWING 7583-12 FOR CONSTRUCTION DETAILS AND ADDITIONAL NOTES.
2. 4" RAD. TO BE CAST IN PLACE AFTER CHAMBER IS IN PLACE, USING EPOXY MORTAR TO OBTAIN ACCURATE ELEVATION. APRON SLAB TO BE CAST LAST TO MATCH OVERFLOW LIP.
3. CONCRETE ALL GRADE 4000 PSI WITH SULPHATE RESISTANT CEMENT UNLESS NOTED OTHERWISE.
4. CRITICAL SURVEY POINTS TO BE VERIFIED PRIOR TO CONSTRUCTION.



ISSUED FOR REPORTING
PURPOSES ONLY

APP. NO.	REVISION	DATE

REFERENCE
CANADIAN SALT COMPANY LIMITED

**EFFLUENT
CONTROL**

PUGHASH, CUMBERLAND CO., NOVA SCOTIA

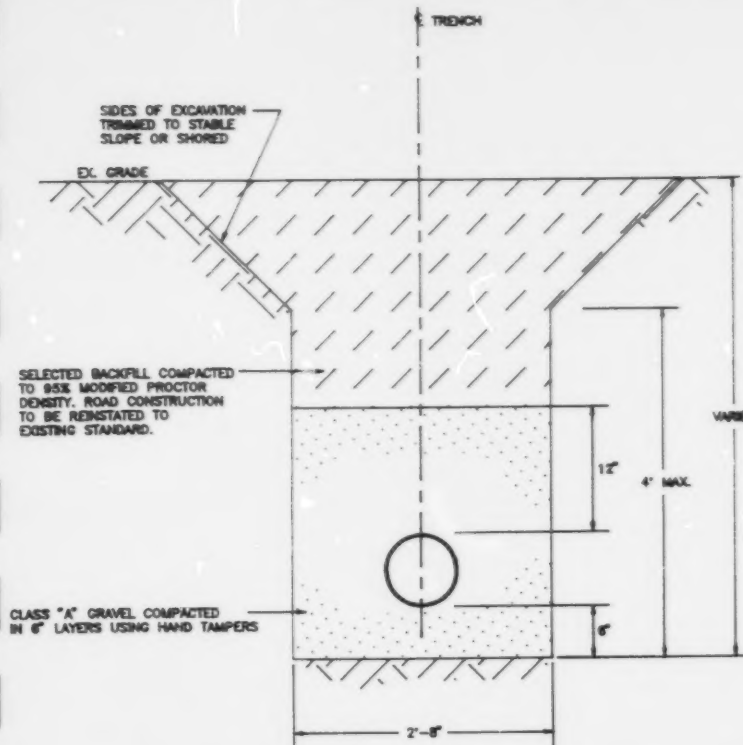
**OVERFLOW DISCHARGE
FROM BRINE POND**

Jacques, Whitford and Associates Limited
CONSULTING ENGINEERS AND ARCHITECTS

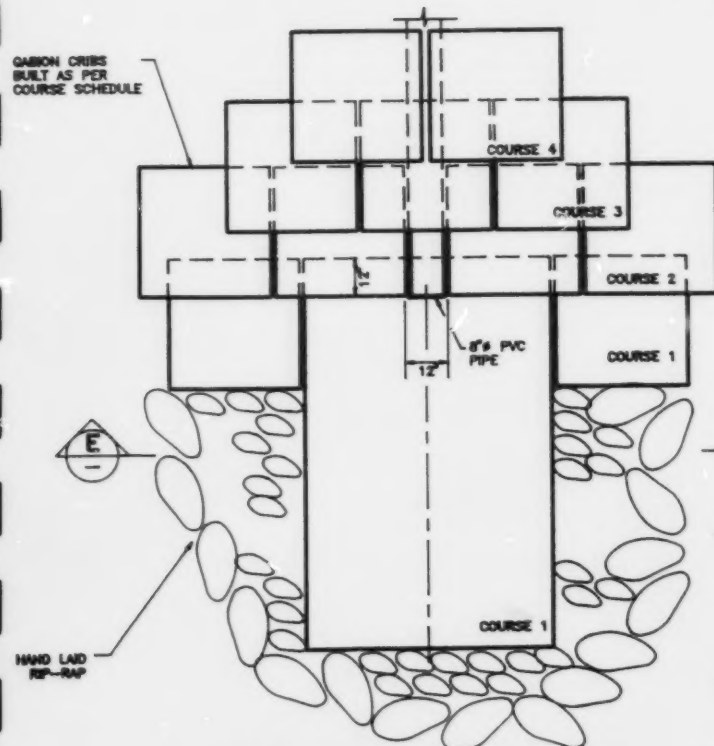
DATE: 01/11/05 SCALE: AS NOTED DRAWN BY: P.J.300



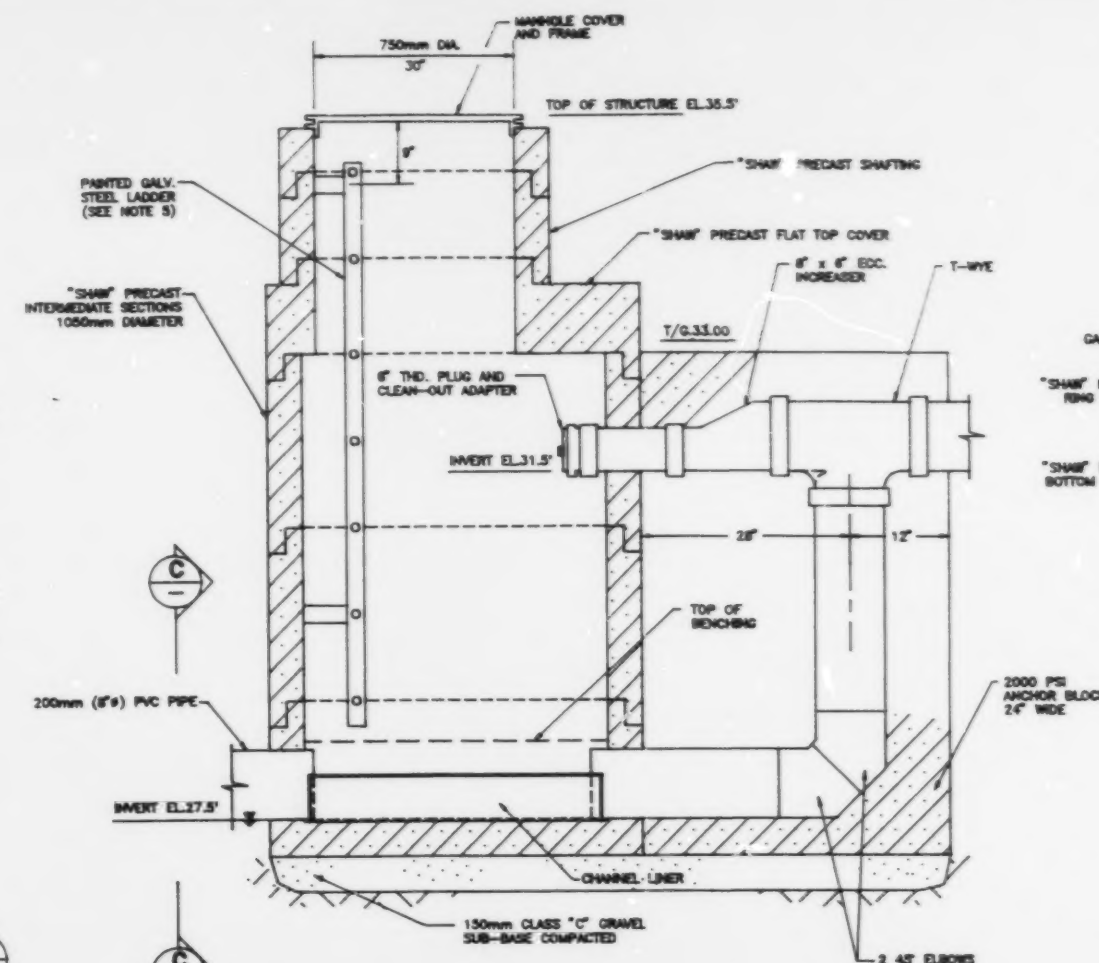
7583-11



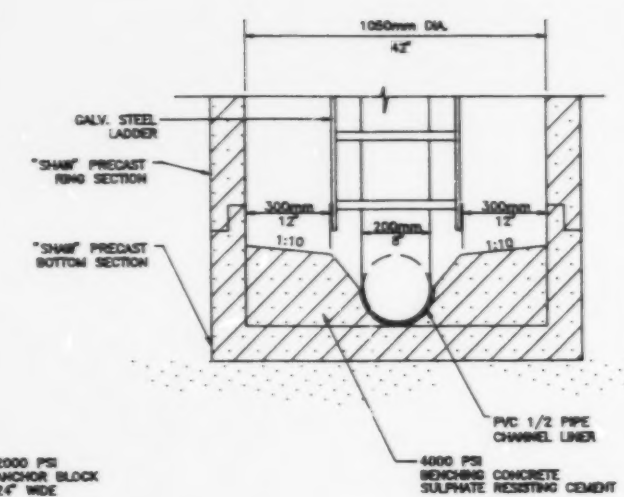
A TYPICAL PIPE TRENCH CROSS-SECTION
N.T.S.



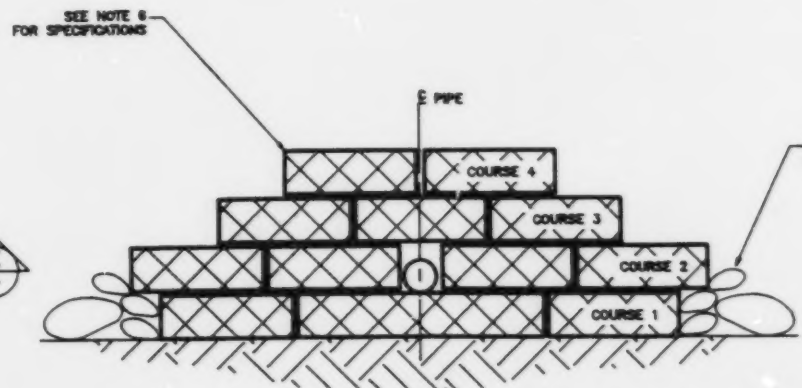
D PLAN OF OUTFALL STRUCTURE
SCALE 1/4" = 1'



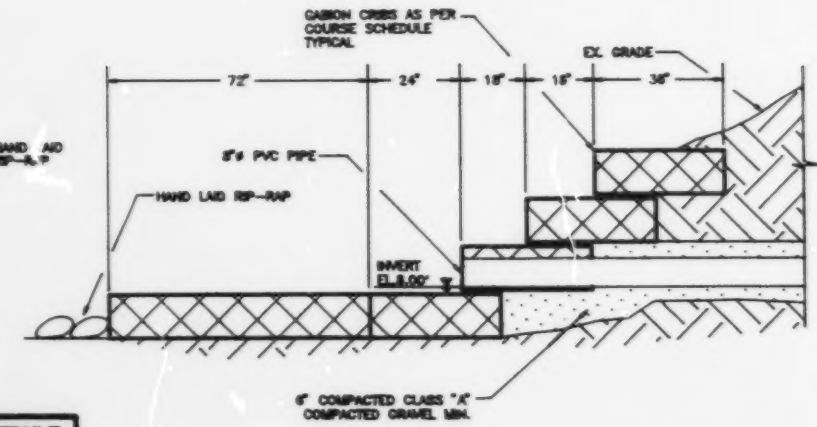
B SECTION THROUGH DROP MANHOLE
N.T.S.



C SECTION SHOWING BENCHING
SCALE 1/2" = 1'



E ELEVATION OF OUTFALL STRUCTURE
SCALE 1/4" = 1'



F PROFILE OF OUTFALL STRUCTURE
SCALE 1/4" = 1'

COURSE SCHEDULE			
COURSE 1	8" x 8" x 12"	1	
COURSE 2	8" x 8" x 12"	2	
COURSE 3	8" x 8" x 12"	4	
COURSE 4	8" x 8" x 12"	2	

GENERAL NOTES:

- REF. DWS 7583-11 FOR PLAN & LONGITUDINAL PROFILE.
- DROP MANHOLE PRECAST CONCRETE SECTIONS TO ASTM SPEC. C-478 GURET TYPE OR EQUAL.
- PIPEWORK AND FITTINGS OF PVC TO ASTM D-3034, (BY SCEPTER PPM OR EQUIVALENT), PIPES OF 30" & MAXIMUM ALL LAB AND INSTALLED IN ACCORDANCE WITH THE MANUFACTURER'S RECOMMENDATIONS.
- PRIOR TO BACKFILLING AND CASTING ANCHOR BLOCK, CONDUCT LOW PRESSURE AIR TEST ON PIPELINES.
- MANHOLE LADDER OF MILD STEEL RUNN 3/4" x 12" LONG AT 12" C/C. LESS OF 1 1/2" x 1 1/2" MILD STEEL PIPES AT 8" C/C WITH 1 1/2" x 1 1/2" MILD STEEL STRAPS WITH 3/4" x 3 1/2" RING PLUGS AND ANCHOR BOLTS. ALL LADDER JOINTS TO BE FILLET WELDED AND ALL MATERIALS TO BE GALVANIZED AFTER FABRICATION AND PAINTED.
- OUTFALL STRUCTURE TO BE CONSTRUCTED FROM "SEA TYPE" MACROFIBRE GABIONS (IN PVC COATED GALVANIZED WIRE) INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS. SIZE OF STONE TO BE APPROX. 8" SINGLE SIZE OF HARD SHALE RESISTANT MATERIAL.

ISSUED FOR REPORTING PURPOSES ONLY

APP. NO.	REVISION	DATE
REV. NO.	DESCRIPTION	DATE
CANADIAN SALT COMPANY		
EFFLUENT CONTROL		
PUDNASH, CUMBERLAND CO., NOVA SCOTIA		
CONSTRUCTION DETAILS		
Jacques, Whitford and Associates Limited		
REGISTERED ENGINEERS AND ARCHITECTS		
DATE	DATE	DATE
01/11/05	AS NOTED	P.J.SOO
DRAWN BY		
CHECKED BY		
PROJECT NO.		
7583-12		

Appendix D

ASA Flow Diffuser Study

**PUGWASH ESTUARY:
BRINE DISPERSION STUDY**

FINAL REPORT

By
Anthony W. Isenor and J. Mark MacNeil

Submitted by
ASA CONSULTING LTD.

February 20, 1992

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1.0 INTRODUCTION

The Canadian Salt Company Limited operates a mine and processing plant in Pugwash, Nova Scotia. Mining and salt refining result in by-products, tailings, and high concentration brine, which are disposed of near the site. The Nova Scotia Department of the Environment requires that remedial measures be put in place to minimize the detrimental impacts of the disposal of this brine.

ASA Consulting Ltd. was contracted to examine scenarios for the disposal of the brine into the Pugwash River. The work consisted of a study of environmental conditions in the region near the plant. Results of this field program are presented in section 2. The information gathered was used in analytical calculations and numerical modelling as described in sections 3 and 4. The analytical calculations represents a highly simplified view of conditions in the estuary but are sufficient to compare the gross features of various discharge alterations. The numerical modelling considers the environmental setting in more detail for a selected brine disposal option.

2.0 FIELD PROGRAM

A field program was undertaken on November 8, 1991 to quantify tidal currents in the estuary, specifically in that area of the estuary near the mine. Tides are important for mixing in the estuary and for the exchange between the estuary and the water of the Northumberland Strait.

The weather on the day of the program was overcast with intermittent moderate wind. The low winds facilitated the program and subsequent interpretation of the data.

2.1 Station Locations and Extent of Data Acquired

Figure 2.1 shows the location of current and water level observations. Bathymetric surveys were also conducted along a line under the Pugwash Bridge and under the pier to the plant's water intake. A brief description of the observational stations is given below.

STATION A - Located under the south span of the Pugwash Bridge. Water depth was approximately 11 metres at slack tide. Collected data include surface, mid-depth and bottom currents, approximately every half hour.

STATION B - Located in the channel opposite the plant. Water depth was 6.7 m at 7:50 am AST (atlantic standard time). Collected data includes surface, mid-depth and bottom currents. Measurements were taken approximately every half hour.

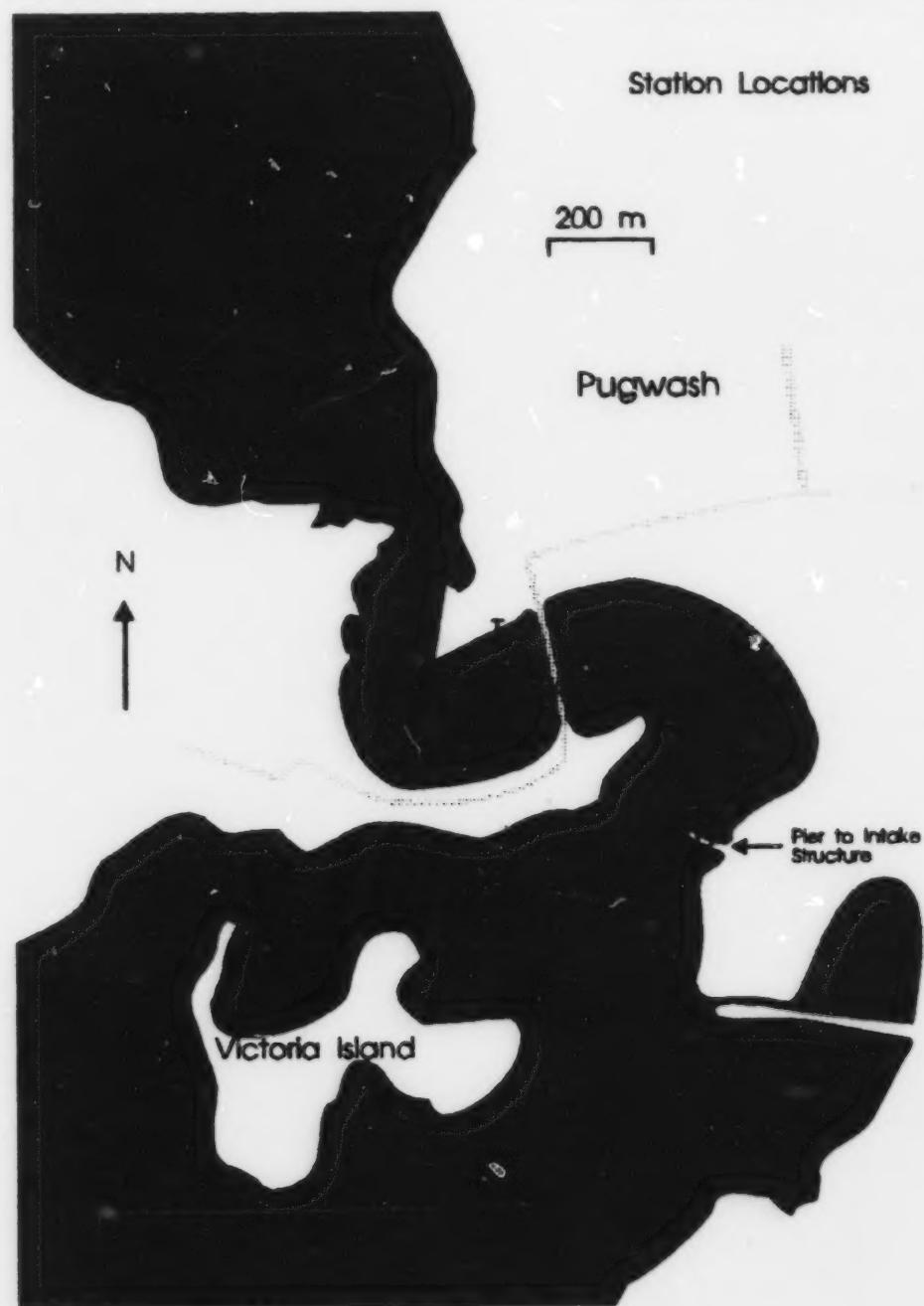


Figure 2.1 Location map for field observations.

STATION C - Located in the channel between Victoria Island and the riprap protected point just south of the plant. Water depth was 11.3 m at 11:00 am AST.

STATION D - Located under the pier of the plant's water intake. Water depth was 7.6 metres at slack tide (1:00 pm AST). Surface currents were recorded every 5 minutes for over an hour. The station was revisited approximately every half hour for the rest of the program.

STATION E - Located off the riprap protected point south of the plant. Station E was located in 1.3 m of water (sounding at 10:47 am AST).

STATION F - During flood and ebb tide, the large currents passing the intake structure create a wake downstream. Station F is located inside this wake on the flood tide. Station F was located in about 4 m of water (sounding at 10:45 am AST).

STATION G - Station G is located inside the wake of the intake structure on the ebb tide north of the plant. Station G was located in 1.5 m of water (sounding at 4:20 pm AST).

STATION T - Relative sealevel was observed at this station using the second steel rung ladder west of the south end of the government wharf as a reference.

2.2 Results and Observations

The observed sealevel data are shown in Figure 2.2. The Figure indicates the change in sealevel relative to a temporary datum established during the field survey (second steel rung on the government wharf ladder).

Figure 2.2 shows the tidal asymmetry on November 8, 1991. The tidal range between the low tide (6:00 am AST) and high tide (12:30 pm AST) was about 2.2 m. Between the high tide (12:30 pm AST) and the low water (18:00 pm AST) the range is about 1.2 m.

The observed currents measured at three depths under the Pugwash Bridge are shown in Figure 2.3. The data indicate a relatively constant current over the entire water column. The currents during flood tide are larger than those during ebb. This is consistent with the asymmetry in the tide for that day.

The currents at Station B are shown in Figure 2.4. Compared to Station A, slight reduction in the currents during flood tide was noted. However, the maximum ebb currents are approximately the same as at Station A. This suggests that the location of maximum flow may change with the tide. Here too, the current field is homogeneous throughout the water column.

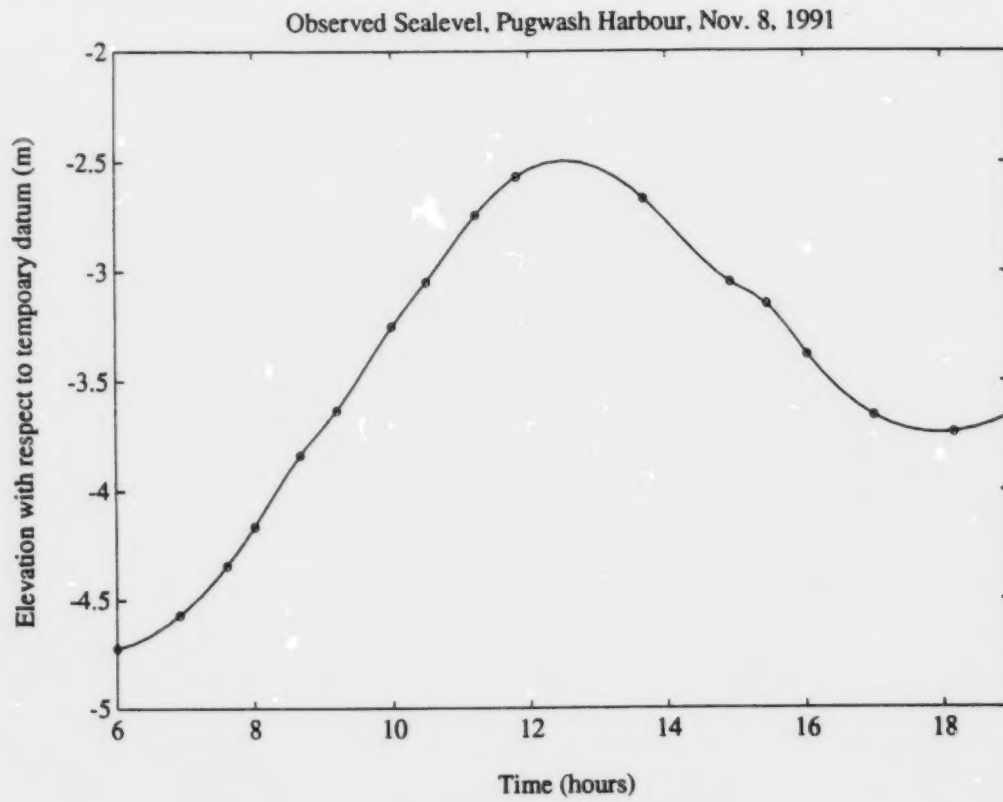


Figure 2.2 Observed sea level.

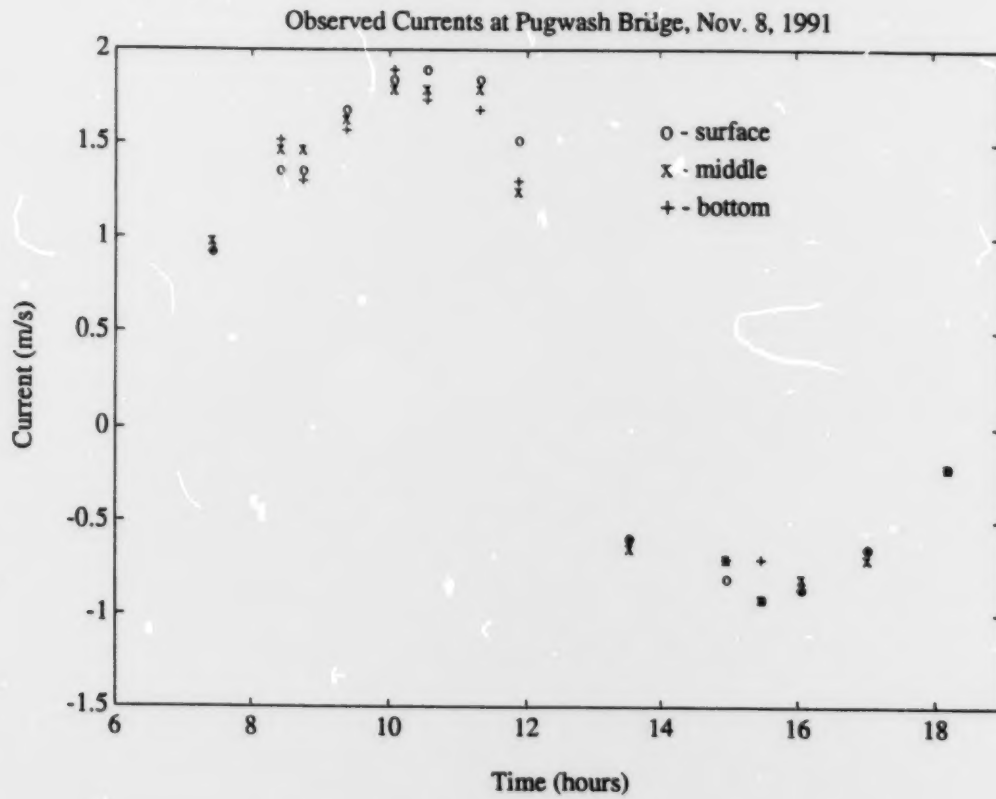


Figure 2.3 Observed currents at Station A.

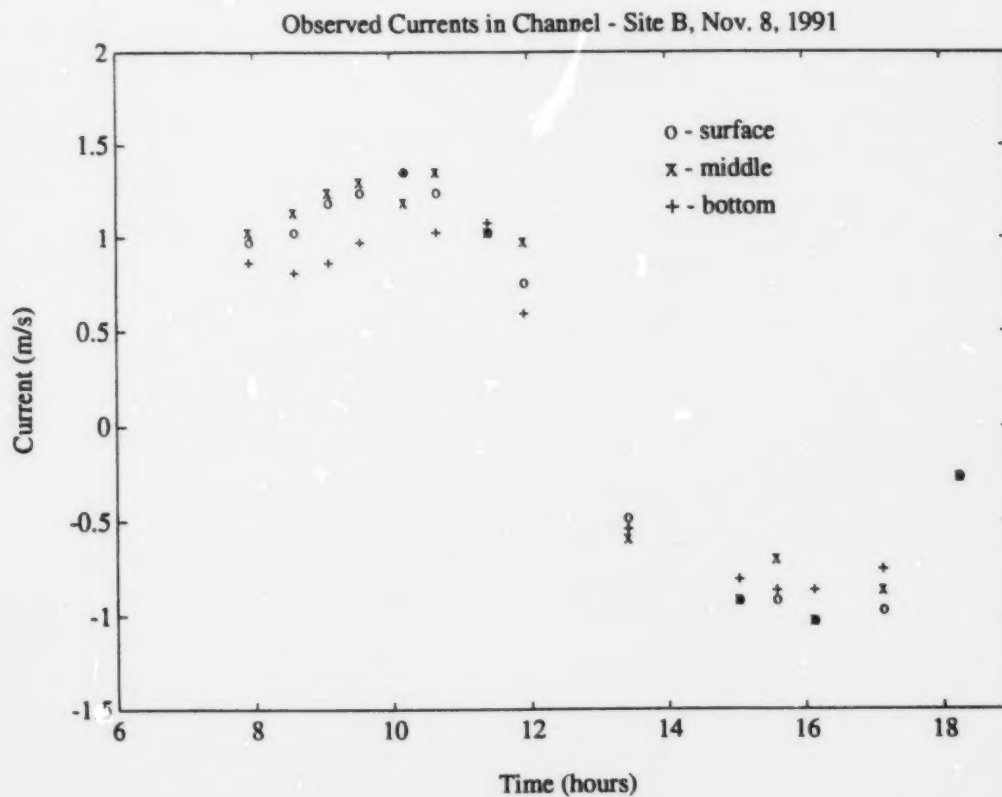


Figure 2.4 Observed currents at Station B.

The currents at Station D, directly under the pier to the intake structure, are shown in Figure 2.5. Again, large currents are noted during ebb. The rapid change in current direction at slack tide is noteworthy. The water speed was below 0.5 m/s for only 40 minutes during the observation period.

Figure 2.6 illustrates the bottom profile under the Pugwash Bridge. Station A was in the deeper channel on the south end of the bridge.

Figure 2.7 shows the bottom profile shoreward of the water intake structure for the mine. The bottom of the pier, water surface and estuary bottom are shown. The intake structure is noted at a horizontal distance of 25 m by an abrupt elevation rise.

Figure 2.8 indicates surface currents measured between 10:33 and 11:33 am AST during flood tide. Figure 2.9 shows the current pattern during ebb tide, between 4:04 and 4:20 pm AST.

A wake is generated as the water flows past the intake structure. At full ebb and flood, the width of this wake is 1.5 to 2 times the diameter of the intake structure and extends for 100 to 200 m downstream.

To the east of this wake, along the shoreline of the plant, an eddy forms in the downstream direction during flood and ebb tide. The eddy is well defined during the flood tide when it is about 75 m by 100 m, and aligned with the shore. The countercurrent near the shore in this eddy was observed to be about 25% of the current at Station D. The influence of the eddy is evident in the current measured at Stations F and G.

3.0 COMPARATIVE ANALYSIS

The following comparative analysis uses analytical methods to examine various outfall options for brine effluent from the salt mine at Pugwash. This analysis will follow the work of Fischer et al. (1979) which presents a comprehensive treatment for such problems.

The water quality objective for the discharge is that the salinity in the receiving Pugwash River Basin not exceed 10% above ambient salinity at 300m distance from the outfall. Thus, before an analysis of possible discharge options is considered, the ambient salinity in the estuary must be determined.

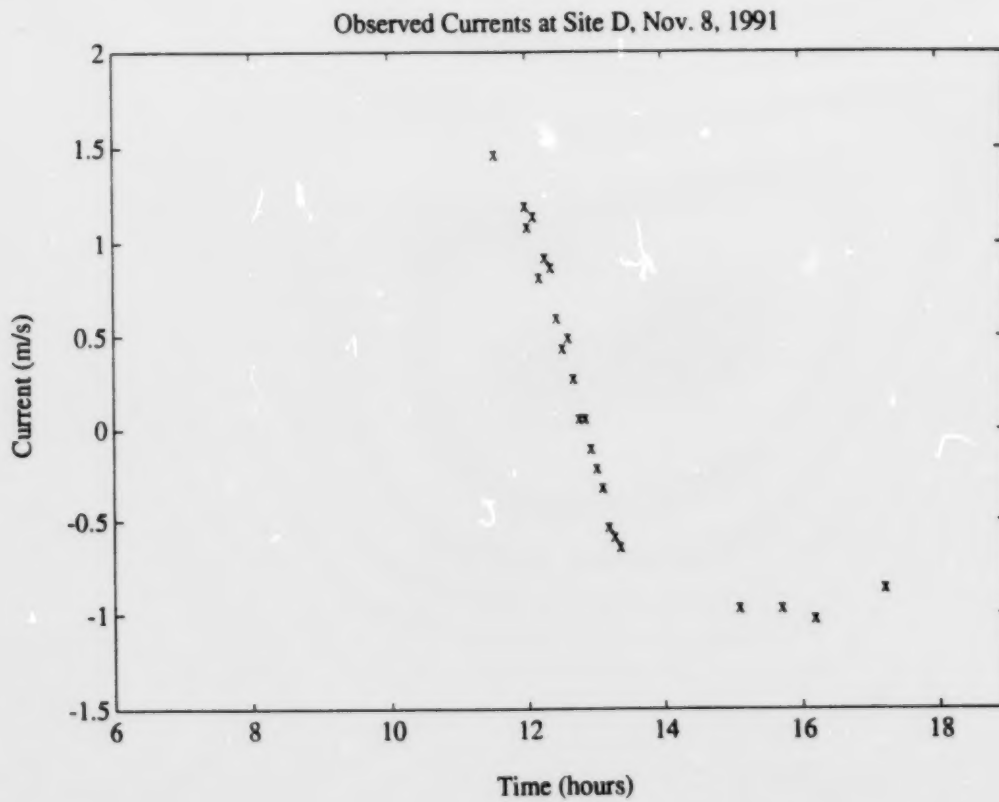


Figure 2.5 Observed currents at Station D.

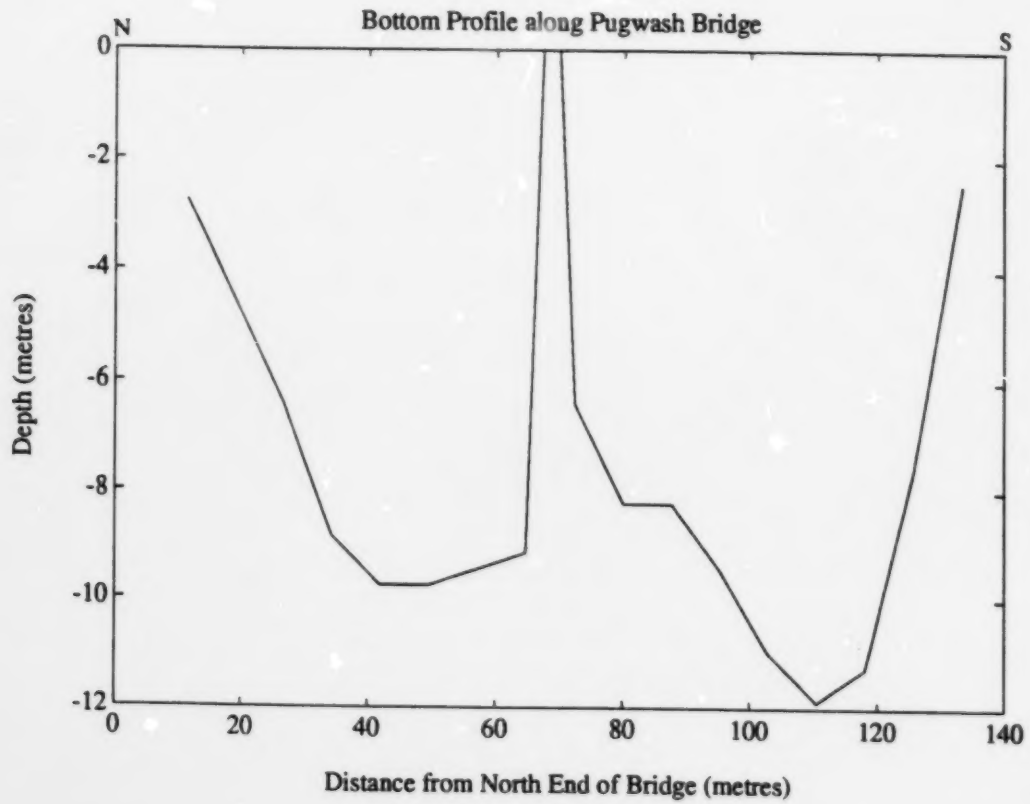


Figure 2.6 Bottom profile under the Pugwash Bridge (data are relative to the same datum as in Figure 2.2).

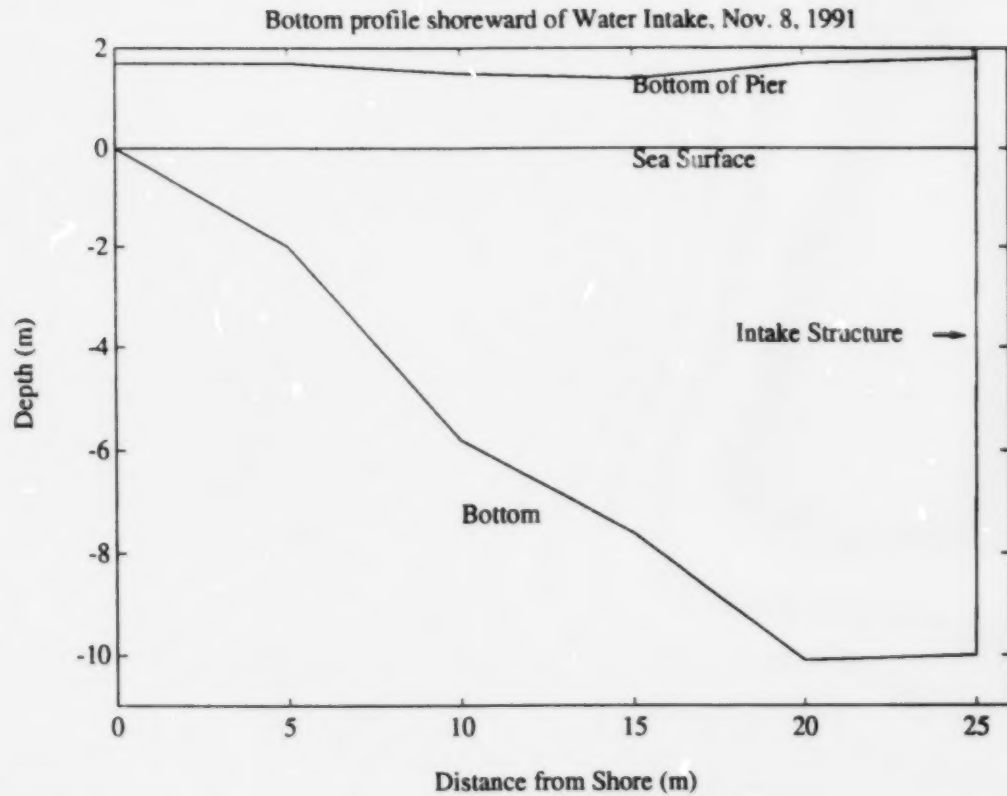


Figure 2.7 Bottom profile under the intake structure (data are relative to the same datum as in Figure 2.2).

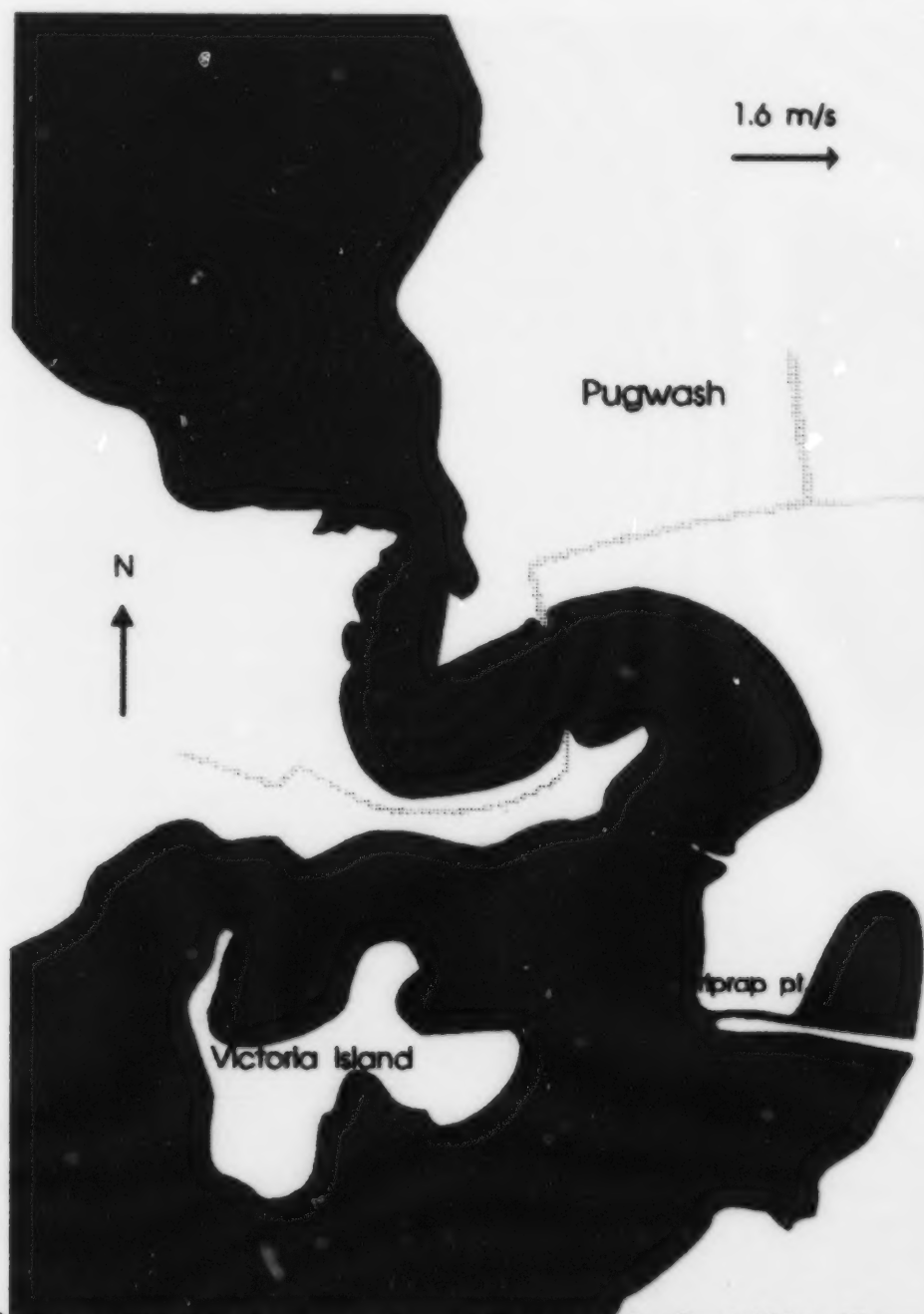


Figure 2.8 Current pattern between 10:33 and 11:33 am AST (during flood tide) on November 8, 1991.

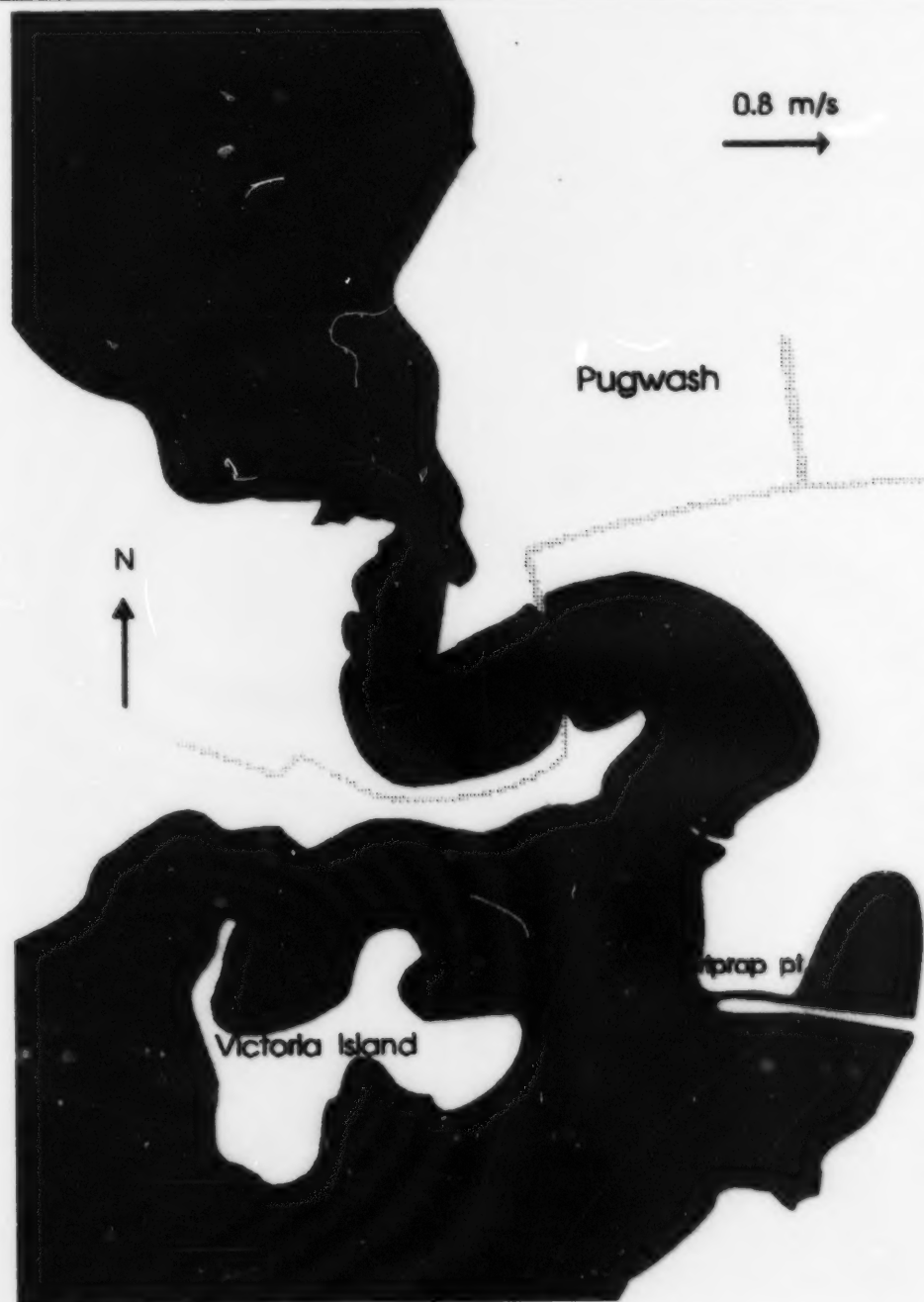


Figure 2.9 Current pattern between 4:04 and 4:20 pm AST (during ebb tide) on November 8, 1991.

3.1 Observed Salinity

A recent field program conducted by Jacques Whitford personnel examined the salinity characteristics of the Pugwash estuary. A total of 6 stations were occupied in or near the main channel. In total 49 measurements of conductivity, salinity and temperature were taken. The salinity values showed a relatively homogeneous water column. The mean of these 49 values is 25.4 ppt (parts per thousand) and the standard deviation is 0.8 ppt. As shown below, these values may be affected by the plant.

3.2 Overall Importance of Brine Release

The mean salinity, current observations presented in section 1, and brine discharge rates can be used to determine the importance of the discharge on measured background salinity. The mean speed of tidal currents under the Pugwash bridge can be computed by integrating over a tide cycle. Assuming a conservative maximum tidal amplitude of 1 m/s, the integration results in a mean of about $\bar{u} = 0.6$ m/s.

Given this mean speed, an estimate of the cross-sectional area under the bridge (~ 460 m²), and assuming the salinity of the incoming water is 25 ppt, one can very simply calculate the amount of salt carried into the estuary with each tide (6.2 hours for flood)

$$(0.6 \text{ m/s}) (460 \text{ m}^2) (6.2 \text{ hr}) (3600 \text{ s/hr}) (25 \text{ kg/m}^3) \sim 150 \times 10^4 \text{ kg}$$

This can be compared to the salt input from the brine effluent over one tidal cycle. With a brine discharge at 45.9 % salt saturation, or 121 ppt and using a background concentration of about 25 ppt, we determine an excess brine discharge of ~ 96 ppt. Using a flow of 0.14 m³/s, the salt input from the mine is

$$(0.14 \text{ m}^3/\text{s}) (12.42 \text{ hr}) (3600 \text{ s/hr}) (96 \text{ kg/m}^3) \sim 0.6 \times 10^4 \text{ kg}$$

Thus, the exchange of salt due to the tides is about 250 times the input due to the effluent. Assuming the water carried in with each tide is pristine and thoroughly mixed with the estuary water after it enters, the effluent would elevate the salinity of the whole estuary by a factor of 1/250 (0.4 %). Taking into account the imperfect flushing by the tide, a 1% increase in overall salinity is more likely. Thus, the effect of the salt mine on the estuary as a whole is small and easily masked by the seasonal change in the Northumberland Strait and runoff from the Pugwash River.

3.3 Required Dilution

Given the ambient salinity and the stated concentration objectives, one may calculate the dilution required to satisfy these objectives. Any designed outfall must satisfy this calculated dilution in order to obtain the concentration objectives.

Assume an observed mean salinity of 25.4 ppt. We recognize in this calculation that this mean is affected by the brine released from the mine. The influence of the mine, as determined above, is to raise the salinity in the estuary by about 1% (~0.3 ppt). Thus, the natural ambient of the estuary is actually about 25.1 ppt. Given the guideline of 10% above ambient, or ~ 2.51 ppt, the objective is to achieve salinities below 27.61 ppt within 300m of the outfall. Using these salinity estimates and a brine input concentration of 121 ppt, we can determine that the plume must be diluted by a factor of about 1:40 within 300m of the outfall to meet the objectives.

3.4 Outfall Options

In the following subsections various outfall options are considered analytically. The various options range from a simple culvert to multi-port diffusers. The options will be presented in terms of the concentration or dilution which results.

The work that follows is by its very nature highly simplified. Analytical solutions for similar problems only exist for very idealized cases. Consequently, numerous simplifying assumptions about the environmental setting will be made. These assumptions may take the form of simplified geometry or order of magnitude estimates for parameters. Regardless, the exercise yields important information concerning the magnitudes of the mixing distances, information required for the numerical modelling which follows.

3.4.1 Present Conditions

The present discharge conditions at the salt mine are very difficult to quantify. There are at least four separate outfalls (two culverts, a breach in the retaining dike, and the hot well discharge) which discharge brine into the estuary. The amount of material being discharged at each of these locations is not known exactly. Seepage and leaching may also result in a distributed source along the shoreline.

Given the complexity of the situation, analytical consideration cannot provide a good estimate of the impact on the estuary without effort beyond the present scope of work. Direct observations by field surveys (eg. plume tracking) is a more appropriate method of determining present day impacts.

3.4.2 Shore Outfall Through a Culvert

A shore outfall through a culvert with a one way valve can be reasonably approximated for conditions that exist in Pugwash. We will proceed by considering a situation where a source of effluent is located along the shore of an estuary.

The effluent is assumed to be at the same density as the water in the estuary, has a concentration of c and be input at a rate of Q . The estuary is assumed to be a straight channel with constant width and depth. The flow in the channel is assumed to be constant at $\bar{u}$ (see Table 3.1). We also assume that the discharge is along the side of the channel (not in an embayment).

Given these assumptions, the concentration of effluent in the estuary can be determined. The maximum concentration at any downstream point will occur along the shore where the effluent is being injected. Along this shoreline, the concentration is given by equation 5.9 in Fischer et al. (1979).

Solving for the required dilution, one determines that the distance required to meet the concentration objectives is about 10m. Thus, about 10m from the discharge point the concentration will be 2 ppt above ambient.

Concentrations would be higher at slack tide because of the low tidal velocities. With no currents, the negatively buoyant effluent will sink and flow along the bottom to the deepest point in the channel. Using various required parameters (see Table 3.2) and Fischer et al. (1979) (see pages 213-218) we estimate that the plume would be ~ 3m thick with a concentration of about 40 ppt when it reached the deepest point in the channel. Considering an outfall near the present location of the breach, this corresponds to a distance of ~ 150m. For bottom dwelling organisms sensitive to salinity and in contact with the brine, this may be considered a worst case.

As the tidal currents increase during ebb or flood tide, ambient turbulence will become sufficient to disperse the plume. This is confirmed by calculating the layer Richardson number

$$Ri = g'h/\bar{u}^2 \quad (\text{eqn. 1})$$

The Richardson number indicates that when the ambient current speed is > 0.8 m/s, the plume will be dispersed.

Table 3.1. Values used in the calculations for a shore discharge of effluent.

channel width = 120 m
 mean current speed = $\bar{u}$ = 0.6 m/s
 channel depth = 10 m
 effluent input = Q = 0.14 m³/s
 effluent concentration = c = 96 ppt

Table 3.2. Values used in the density driven plume calculation.

bottom slope = 0.05
 triangular plume section = 90°
 initial plume thickness = 1m
 bottom drag coefficient = 0.016

Table 3.3. Values used in the single port diffuser calculations.

effluent density = ρ_e = 1121 kg/m³
 ambient density = ρ_a = 1022 kg/m³
 effluent input = Q = 0.14 m³/s
 acceleration due to gravity = g = 10 m/s²
 terminal height of rise = z_t = 10 m

Table 3.4. Characteristics of the diluted plume assumed in the single port diffuser calculation.

partially mixed effluent input = 3.5 m³/s
 partially mixed effluent density = 1080 kg/m³

These two calculations indicate that on the mean the objectives are likely to be met by a shore outfall. On an intermittent basis, however, a bottom plume with concentrations exceeding the objectives could form at slack tide and last for a few hours. It is difficult to draw firm conclusions from these analytical calculations for a discharge at the present culvert location (in the embayment formed by the breach).

3.4.3 Single Port Bottom Diffuser

Now consider a single port diffuser located at the bottom of the channel. Again, various simplifying assumptions must be made before an analytical solution can be found.

The outflow from a single port diffuser is treated as a negatively buoyant jet released in an infinite ambient fluid. Initially, the jet will be propelled upward by its initial velocity. Eventually, however, the negative buoyancy will cause the effluent to fall towards the bottom.

If the jet is directed vertically, maximum dilution is achieved when the plume rises the full extent of the water column before sinking. Using values given in Table 3.3, we may determine the exit velocity of the effluent from the diffuser (Fischer et al., 1979, equation 9.53; Turner, 1966)

$$z_t \sim 2 (vQ)^{3/4} / (g'Q)^{1/2} \quad (\text{eqn. 2})$$

where

- z_t is the terminal height of rise,
- Q is the rate of effluent input,
- $g' = g (\rho_e - \rho_a) / \rho_a$ is the reduced gravity,
- g is the acceleration due to gravity,
- ρ_e is the density of the effluent,
- ρ_a is the density of the ambient, and
- v is the discharge velocity of the effluent.

We estimate the exit velocity to be $\sim 16\text{m/s}$. Assuming a round jet, one can calculate the mean dilution at the surface to be 1:25 (Fischer et al, 1979, table 9.2).

Further dilution occurs as the plume falls from its maximum height of rise. We assume that the ambient flow is sufficient to move the effluent at the surface to an area where there is pristine water beneath it. The plume at the surface has new characteristics as given in Table 3.4. Given these characteristics, one can determine the volume flux of the plume when it reaches the bottom to be $\sim 8\text{m}^3/\text{s}$ (Fischer et al., 1979, table 9.3). Compared to the initial flux of $0.14\text{m}^3/\text{s}$, this is a dilution of ~ 55 and corresponds to a concentration of $\sim 27\text{ppt}$.

Discharging the effluent at an angle as opposed to vertical as in the above calculation would reduce the vertical extent of the plume. Dilution estimates (Zeitoun et al. 1970, Pincince and List, 1973) for a jet at 60° at the point of maximum rise of the jet is 1:25, similar to the previous estimate. An inclined jet introduces horizontal momentum and is therefore advantageous when ambient currents are low.

These calculations indicate that a single port diffuser discharging the effluent with an outflow velocity of 16m/s in 10m of water could meet the objectives. However, this exit velocity would require pumping as the pressure head required to produce such velocities would be about 13m. If a gravity flow were used (assume 1m head) then the dilution would be reduced to 1:5 at the terminal rise height. A similar (possibly larger) reduction in the dilution would be noted when the plume impacted the bottom.

3.4.4 Multiport Bottom Diffuser

In considering a multiport bottom diffuser, we examine the case where the negative buoyancy of the brine is neglected. After the effluent has been discharged from the diffuser and the individual plumes have merged to form a sheet, estimates of the dilution can be obtained by considering the plane jet solutions (Fischer et al. 1979, table 9.2). If we assume a discharge velocity of 10m/s (5m head), the effective slot width of the diffuser is about 0.007m. Assuming the plume spreads vertically over the water column (10m), the dilution is about 1:40 for a diffuser 2m in length. This is approximately the dilution required to meet the objectives. Actual dilutions could be expected to be less because of the influence of negative buoyancy. The effect of a reduction in the exit velocity is difficult to determine as the model assumptions no longer apply at small velocities.

Another approach which accounts for the buoyancy of the effluent assumes that the effluent forms a horizontal sheet at the bottom. The thickness of the sheet can be estimated by the ambient flow $\bar{u}$, the diffuser length L , and the effluent flux Q . The estimated thickness is

$$h = Q/(\bar{u}L) \quad (\text{eqn. 3})$$

Given previous values for $\bar{u}$ and Q and assuming a diffuser length of 2m, one determines a thickness of about 0.1m.

To determine whether or not such a layer could be destroyed by the ambient flow, we consider the Richardson number (see eqn. 1). In this case, $Ri < 1$, indicating that the layer would be mixed by the ambient flow.

4.0 NUMERICAL SIMULATIONS

The simplifying assumptions of the analytical work presented above are not required in computer simulations. Variations in the bathymetry, the meandering shoreline, variations in water depth due to the tide, and the changing tidal current patterns can all be accounted for in numerical simulations. These simulations predict the spatial and temporal concentration of brine effluent for a specified outfall scenario.

The model does not consider the vertical distribution of the effluent plume. It was determined in section 3.4 that under some circumstances (slack tide) the plume may sink to the bottom. Under these conditions, the numerical model gives an average concentration throughout the water column. In reality, surface salinities are expected to be lower than model predictions and bottom salinities higher than model predictions.

4.1 The Model Domain

The numerical modelling presented here relies on the combination of a hydrodynamic model and a brine dispersion model. Both of these models consider the same spatial area, which stretches from the Pugwash Bridge to 1.8 km upriver, beyond Victoria Island (Figure 4.1). The model domain represents an area of about 0.9 km².

The model domain is subdivided into model cells. For the Pugwash application, the model cells are 50m X 50m in size. This resolution permits a detailed examination of conditions near the discharge point and resolves the shape of the River channel.

The bathymetry used in defining the water depth in each model cell were measured by Jacques Whitford and Associates. The bathymetric soundings presented in section 1.0, topographic chart 11E/13, and hydrographic chart 4498 were used to estimate the general shape and depth of the river. An aerial photograph (MMRS, 1985) was also referenced to characterize more recent changes to the gross features of the estuary. However, these data were not sufficiently dense to define a depth to each model cell and subjective interpolation and extrapolation was used to determine the depth of some model cells.

4.2 The Hydrodynamic Model

A two-dimensional hydrodynamic model (2DMULT Ver. 2.2.2) of the Pugwash River was used to estimate the temporal evolution of the water velocity and water depth over the model domain. This model has been developed at ASA over many years and has recently been applied in numerous locations (de Margerie et al. 1990; de Margerie and Isenor, 1990; Hurlbut et al. 1991).

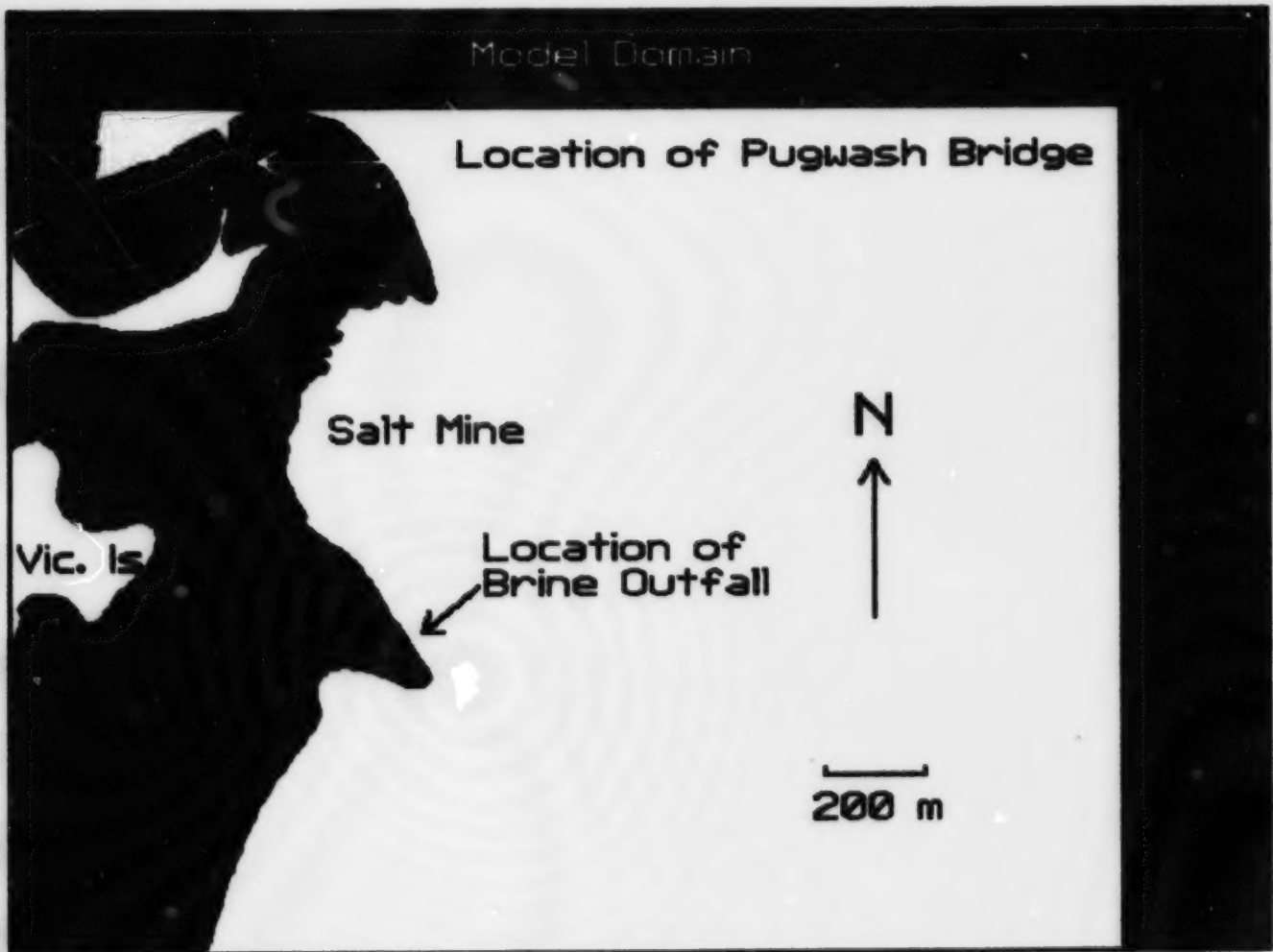


Figure 4.1 Area considered by the brine dispersion model.

The equations solved by the hydrodynamic model for each model cell are:

$$\frac{\partial \bar{U}}{\partial t} + \bar{U} \cdot \nabla \bar{U} + \bar{f} \times \bar{U} = -\nabla g z + K \nabla^2 \bar{U} - (C_d/h) |\bar{U}| \bar{U} \quad (\text{eqn. 4})$$

$$\frac{\partial z}{\partial t} = -\nabla \cdot \bar{U} h \quad (\text{eqn. 5})$$

where

$\bar{U}$ is current velocity,

$\bar{f}$ is the Coriolis parameter (accounts for earth rotation),

g is the gravitational acceleration,

z is water surface elevation,

K is a turbulent diffusion coefficient,

C_d is a bottom drag coefficient,

h is water depth, and

∇ and ∇^2 are the divergence and Laplace differential operators.

This equation is solved explicitly, using a finite difference technique. For the modelling presented here, the bottom drag coefficient was set to 0.003. This value is consistent with other nearshore or estuary studies. The turbulent diffusion coefficient was set to 10 m²/s.

Currents were estimated by specifying an elevation difference between the two open boundaries of the model, at Pugwash Bridge and south of Victoria Island. The resulting current field was then scaled such that the maximum flood and ebb tidal currents under the Pugwash Bridge were approximately 1 m/s, as observed (see section 1.2).

One of the unique features of this hydrodynamic model is its ability to account for tidal mud flats. The tide causes water level variations in the River which change the bathymetry influencing the water mass. At low tide, some areas of the River are exposed while at high tide these areas are covered with water. The hydrodynamic model accounts for these variations both in terms of the water elevation and current field.

The hydrodynamic model produces a conservative flow field, which conforms to constraints of the topography. Intrinsic in this application is the assumption of linearity, which cannot reproduce the eddies observed in the field program.

4.3 The Brine Dispersion Model

The two-dimensional brine dispersion (2DTRANS Ver. 1.03) model uses the current field generated by the hydrodynamic model and the anticipated brine concentration and discharge rate to predict the concentration of brine throughout the model domain. The model assumes that the brine plume is vertically well mixed, an assumption validated by the comparative analysis presented in section 2.4.2. This model has been used in numerous recent studies involving effluent plumes (de Margerie et al. 1990; de Margerie and Isenor, 1990; Hurlbut et al. 1991).

The model simulations consider the excess salinity due to brine release. Actual salinities can be obtained by adding the natural ambient salinity (25.1 ppt) to the results that follow.

The equation solved by the brine dispersion model for each model cell is :

$$\frac{\partial hB}{\partial t} = - \nabla \cdot \bar{U}ht + hN\nabla^2 T + S \quad (\text{eqn. 6})$$

where

B is the excess brine (above normal ambient),

t is time,

$\bar{U}$ is the horizontal velocity,

h is the plume thickness,

N is the horizontal diffusion coefficient,

S is a brine source term (S=0 except at the plant outfall)

∇ and ∇^2 are the divergence and Laplace differential operators.

This equation is solved explicitly, using a finite difference technique.

The horizontal diffusion term (N) is used to parameterize the effect of variability not otherwise included in the model. This includes high frequency motion, large scale eddies and turbulence not reproduced in the specified ambient current field. A large horizontal diffusion coefficient will lead to faster dispersion and lower brine concentrations.

Estimates of N in natural bodies of water typically range between 3 m²/s and 1300 m²/s (Fischer et al., 1979). A value of N = 1.0 m²/s was considered conservative for the modelling presented here. Using a minimum dispersion coefficient will result in a worst case estimate of the effluent concentration near the outfall.

In all the simulations, the effect of the brine effluent is assumed to be negligible outside of the model domain and is fixed at zero.

The amount of brine discharged by the Mine into the Pugwash River was supplied by Jacques Whitford and Associates. The brine discharge consists of effluent at 45.9 % salt saturation, or ~121 ppt. Considering the ambient of about 25 ppt, the excess salinity of the discharge is ~ 96 ppt. Using a discharge flow of 2200 USGPM or 0.14 m³/s, we have an excess brine input of ~ 13.4 kg/s. The value 13.4 kg/s is used as input for the brine dispersion model.

The model assumes that the effluent input is constant through time. Small variations in the input will have correspondingly small effects on the results presented below.

4.4 Brine Dispersion Model Results

The results of the brine dispersion model are presented in graphical form in Figures 4.2 - 4.5. Each Figure shows the entire model domain with the general Mine area and Victoria Island indicated. The color salinity scale ranges from 0 to 2 ppt and is the concentration of salt above background, termed excess concentration. The upper limit of this scale is approximately 10% of the ambient salinity. A north arrow and distance scale are also included.

Figure 4.2 shows the model results at low tide. Note that the areas of the River which are exposed are colored brown. At low tide, the discharge is above the water line and will flow down the exposed littoral zone. This region is not represented by the model. The maximum excess concentration at low tide is estimated at ~ 6 ppt. The total area effected by the discharge is about 10000 m². The offshore extent of the effected area is about 100 m.

Figure 4.3 shows the model results at high tide. The small embayment where the discharge is located (see Figure 4.1) has excess concentrations over 2 ppt. The maximum excess concentration in this embayment is about 20 ppt. The excess concentration drops to less than 2 ppt at 100 to 200 m from the discharge location. The area effected with excess concentrations greater than 2 ppt is about 25000 m².

The predicted excess concentrations at the time of maximum flood currents are presented in Figure 4.4. The maximum excess concentration near the area where the discharge stream contacts the River water is about 1.5 ppt. The effluent plume is directed upriver about 200 to 300 m (the 0.2 ppt contour). The 0.2 ppt contour is about 100 m from the shoreline at mid-tide.

Figure 4.5 shows the model results at the time of maximum ebb currents. The maximum excess concentration is about 1.4 ppt near the area where the discharge stream contacts the River water. The brine plume is directed downriver. The 0.2 ppt contour is about 400 to 500 m from the discharge stream.



Figure 4.2 Predicted brine concentration at low tide. Areas that are above the water line are colored brown. The color scale is from 0.0 to 2.0 ppt above ambient.

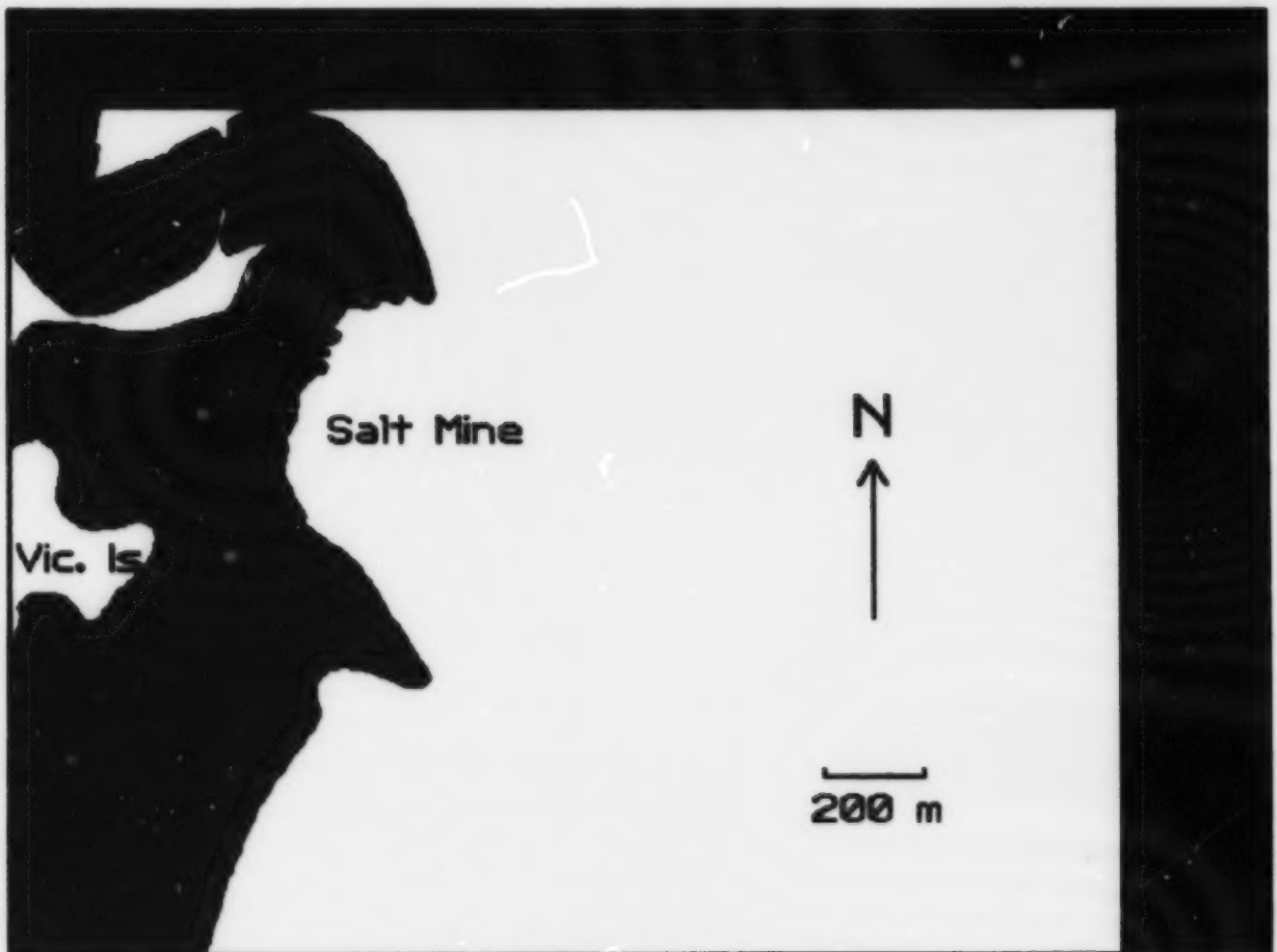


Figure 4.3 Predicted brine concentration at high tide. The color scale is from 0.0 to 2.0 ppt above ambient.



Figure 4.4 Predicted brine concentration at the time of maximum flood currents. Areas that are above the water line are colored brown. The color scale is from 0.0 to 2.0 ppt above ambient.



Figure 4.5 Predicted brine concentration at the time of maximum ebb currents. Areas that are above the water line are colored brown. The color scale is from 0.0 to 2.0 ppt above ambient.

5.0 SUMMARY OF RESULTS

The oceanography of Pugwash Harbour in the area near the salt mine was determined using collected data. Currents and water levels were observed over a period of 13 hours. In general, the area is dominated by the tides, consequently, conditions in the estuary are characterized by large tidal currents.

Based on the analytical and numerical modelling presented, a shore discharge through a one way culvert produces excess concentrations ranging up to about 20 ppt at high tide. During high tide, the small embayment where the discharge culvert is located experiences the maximum excess concentration due to the shallow nature of the embayment. However, conditions at other stages of the tide cycle are typically less than 2 ppt. In all estimates presented, the excess concentration drops to less than 2 ppt within 200 m from the contact point of the brine effluent and the River water and thus meets the stated objectives (10% at 300m). This indicates that the present outfall practice is a reasonable way to meet these objectives.

6.0 REFERENCES

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Appendix E

Chemical Analysis - Data Sheets

MINERALS ENGINEERING CENTRE



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10 November, 1991

Jacques, Whitford & Associates Ltd.,
c/o Spectacle Lake Drive,
Dartmouth, N.S.:
B3B 1W8

Attention: D. Georgiou

Re: Results of analyses on submitted samples.

Project: 7583

Sample & % wt.			
Size (mm)	SA 6	SA 9	SA 10
+2		42.53	18.2
-2+1		12.88	2.90
-1+0.5		2.51	1.38
-0.5+0.25	9.31	2.06	3.82
-0.25+0.15	22.99	5.40	10.87
-0.15+0.075	19.37	6.22	16.25
-0.075+0.0375	12.74	6.07	16.30
-0.0375+0.01875	5.86	3.47	7.13
-0.01875	29.08	15.76	22.53
	100.00	100.00	100.00

Sample	Na	Cl	CaO	SO3	NaCl	CaSO4
SA #6	7.48	11.06	33.24	47.39	15.23	50.56
SA #9	0.61	0.87	39.33	47.60	1.36	50.77
SA #10	0.16	0.25	39.37	55.37	0.42	54.15

by J. Cole
J. Cole

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29 November, 1991

Jacques, Whitford & Associates Ltd.,
3 Spectacle Lake Drive,
Dartmouth, N.S.,
B3B 1W8

Attention: D. Georgiou

Re: Results of analyses on submitted samples.

Project: 7583 Pugwash

Sample	%						
	Na	Cl	CaO	SO3	NaCl	CaSO4	H2O+
#1	0.36	0.56	39.07	53.96	0.92	91.75	1.34
#2	0.80	1.36	39.02	52.81	2.24	89.80	0.27
#3	0.33	0.53	38.11	53.58	0.87	91.10	3.37
#4	0.67	1.20	38.70	52.85	1.98	89.89	1.43
#5	0.34	0.55	38.70	53.82	0.91	91.51	1.68
#6	0.02	0.03	36.80	50.25	0.04	85.44	6.80
#7	0.02	0.03	37.77	52.10	0.04	88.59	5.93

Sample	%	
	Gypsum	Anhydrite
#1	6.40	86.69
#2	1.29	88.78
#3	16.10	78.36
#4	6.83	84.46
#5	8.03	85.16
#6	32.49	59.73
#7	28.33	66.17

Cyril Cole
Cyril Cole